

AR5: “It is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together. The best estimate of the human- induced contribution to warming is similar to the observed warming over this period.” (IPCC, 2013)

AR6: “The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.” (IPCC, 2021)

The AR4 and AR5 attribution statements reference the warming since the mid-20th century, the period when greenhouse gas emissions began rapidly increasing. The words “most” and “more than half” are deliberately imprecise, potentially ranging from 51 to 99% of the warming – presumably this imprecision is to account for structural uncertainties such as natural internal variability. The confidence level increases from *very likely* to *extremely likely* from AR4 to AR5. The structure of the attribution statement in the AR6 is fundamentally different, referencing the warming to the period 1850-1900. The AR6 attribution statement is more precise numerically, but with a lower level of confidence at “likely” – the AR6 attributes essentially all of the warming to increases in greenhouse gases. The most confident statement from the AR6 relates to the tropospheric warming since 1979, using the words “main driver” and “*very likely*.”

There are three areas of substantive criticism of the IPCC assessment of the causes of the recent warming: inadequate assessment of natural climate variability, inappropriate statistical methods, and substantial discrepancies between models and observations. The latter is discussed in Chapter 7. The other two factors are discussed herein. Both of these issues are relevant not only in context of the main policy-relevant statement of the IPCC concerning attribution of the recent warming, but also because the global warming attribution provides the basis for extreme event attribution

7.3.1 Natural climate variability

The IPCC AR6 states that natural external drivers since 1850-1900 have changed global surface temperature by –0.1°C to +0.1°C, and internal variability has changed it by –0.2°C to +0.2°C – on average, having essentially no net impact on the warming since 1850-1900. This assessment of the contributions of natural variability has been disputed by a number of publications that question the magnitudes of the contributions from solar forcing and internal variability from the large-scale ocean circulations (R Connolly et al., 2021; W Soon, 2023).

If the Equilibrium Climate Sensitivity to CO₂ is low (Chapter 5), then natural climate variability becomes more important in the attribution of the recent warming. Further, if natural variability is higher, then estimates of the Equilibrium Climate Sensitivity from the historical period would be lower (Scafetta, 2023).

Solar variability

The IPCC AR5 concluded that the best estimate of radiative forcing due to Total Solar Irradiance (TSI) changes for the period 1750–2011 was 0.05 W/m^2 (Myrhe et al., 2014). The IPCC AR6 acknowledges a much larger range of estimates of changes in TSI over the last several centuries, stating that the TSI between the Maunder Minimum (1645–1715) and the second half of the twentieth century increased by $0.7\text{--}2.7 \text{ W/m}^2$, a range that includes both low and high variability TSI data sets (Gulev, 2021). However, the recommended forcing dataset for the CMIP6 climate model simulations used in the AR6 for attribution studies averages two data sets with low solar variability (Matthes, 2017).

While the IPCC AR6 shows a substantially greater solar impact than does the AR5, the overall impact on the climate was assessed to be small compared to anthropogenic forcing of climate change. However, the impact of solar variations on the climate is uncertain and subject to substantial debate – something that you would not infer from the IPCC assessment reports (Lockwood, 2012; Connolly et al., 2021).

Exactly how TSI has changed over time has been a challenging problem to resolve. Since 1978, there have been direct measurements of TSI from satellites. However, the data exhibit non-negligible inconsistencies, and interpreting any multi-decadal trends in TSI requires comparisons of observations from overlapping satellites. There are several rival composite TSI datasets, disagreeing as to whether TSI increased or decreased during the period 1986–96 (the ACRIM gap; see Chapter 4). Further, the satellite record of TSI is used for calibrating proxy models, whereby past solar variations are inferred from sunspots and cosmogenic isotope measurements (Velasco Herrera et al., 2015).

There is substantial evidence for high solar activity in the second half of the 20th century (starting in 1959) and extending into the 1990's, before a decline in the early 21st century; this period is often termed the “Modern Maximum.” (Chatzistergos et al., 2023; Solanki et al., 2004; Usoskin et al., 2007). However, some scientists have concluded that it is not possible to be confident of any multi-decadal trend in TSI (Schmutz, 2021).

As a result of this uncertainty, some reconstructions for past values of TSI (since 1750) have low variability, implying a very low impact of solar variations on global mean surface temperature, whereas datasets with high TSI variability can explain more than 70% percent of the temperature variability since preindustrial times (Scafetta, 2013; Stefani, 2021). Hence, the choice of which TSI satellite record used in an analysis can substantially influence how much climate change is attributed to human versus natural forcings.

There is growing evidence that other aspects of solar variability, which are referred to as solar indirect effects, amplify TSI forcing or are independent of TSI forcing. Scafetta et al. (2023) suggests that ~80% of solar influence on climate may stem from non-TSI mechanisms. Candidate processes include: solar ultraviolet changes; energetic particle precipitation; atmospheric-electric-field effect on cloud cover; cloud changes produced by solar-modulated galactic cosmic rays; large relative changes in the magnetic field; and the strength of the solar wind. Solar indirect effects are not included in climate models, although indirect methods of estimating these effects suggest

significant influence. However, claims of non-TSI mechanisms influencing climate are uncertain and debated.

Natural variability of large-scale ocean circulations

Variations in global mean surface temperature are linked to recurrent large-scale variations in ocean circulation patterns. These circulation patterns include the Atlantic Multidecadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO) and the El Nino-Southern Oscillation (ENSO). These circulation patterns influence ocean heat uptake and heat distribution, and also influence atmospheric circulation patterns and cloud distributions. There is some debate as to whether these variations are strictly internal to the climate system, or whether this variability can have a solar/astronomical origin or can be influenced by large volcanic eruptions.

While climate models simulate the large-scale ocean circulations and internal climate variability, the simulated magnitude in the multi-decadal band is too low in most models relative to observations, and the phasing of the variability in long-term climate simulations is not synced with the actual, observed climate variations (Kravtsov et al. 2024). Averaging multiple simulations from climate models effectively averages out the internal variations, leaving only the forced climate variability (e.g., CO₂ forcing). With most of the modern warming beginning in the late 1970's, the recent 50-year warming is on the same time scale as the multi-decadal oscillations of the AMO and PDO.

Here are summary statements from the IPCC AR5 and AR6 reports:

“Decadal variability in the Pacific, associated with the PDO or IPO, contributes significantly to regional and global temperature trends, but the relative contributions of internal variability and external forcing are difficult to disentangle in CMIP5 simulations.” (IPCC, 2013)

"Since AR5, there has been increased understanding of the role of internal variability, such as ENSO, PDO, and AMO, in modulating regional climate trends. However, limitations in simulating the exact timing and amplitude of these modes in CMIP6 models contribute to uncertainties in attributing observed changes to anthropogenic forcing (high confidence)." (IPCC, 2021)

The amplitude of the peak-to-trough impact of the multi-decadal oscillations on global temperatures has been assessed by the IPCC AR6: “The likely range of change due to internal variability is -0.2°C to +0.2°C (IPCC, 2021).” This implies a trough-to-peak change of 0.4°C. Over many centuries, any global temperature changes from the troughs and peaks will cancel out, with little to no net impact.

However, with a nominal timescale of 60-80 years for oscillations such as the AMO and PDO, the timing of the peaks and troughs can be confused with the secular trend. This becomes very relevant for attributing the warming for the 50 years since 1975, during which most of the warming has occurred. Even if climate models have the correct amplitude of the multidecadal oscillations, the timing of the peaks and troughs is not adequately simulated, with each model and individual

ensemble simulating a different phasing. Once the simulations of the ensemble members and different models are averaged, the natural internal variability contribution is averaged out, effectively cancelling the role of natural internal variability in the attribution process.

The Great Pacific Climate Shift of 1976-1977 was a notable climatic event characterized by an abrupt change in the North Pacific Ocean's atmosphere-ocean system that interacted with global climate patterns. This shift is closely associated with the Pacific Decadal Oscillation (PDO) that oscillates between warm and cool phases over decades. The 1976 shift marked a transition from a predominantly negative (cool) PDO phase (1947–1976) to a positive (warm) phase (1977 through 2000), with significant implications for global and regional climate patterns including the frequencies of El Nino and La Nina events. The Great Pacific Climate Shift coincided with the beginning of a period of accelerated global warming (REF TO A FIG OF GLOBAL TEMP ANOMALIES ELSEWHERE IN DOC) When the Great Pacific Climate Shift is accounted for in climate attribution analyses since 1950, it has been found that 40 percent or more of the warming in the second half of the 20th century was caused by natural internal variability (McLean et al., 2009; Tung and Zhou, 2013; Chylek et al., 2016; Scafetta, 2021).

7.3.2 Optimal fingerprinting

Optimal fingerprinting is a statistical technique introduced by Allen and Tett (1999) that compares observed climate data to climate model simulations to identify patterns (or "fingerprints") associated with human or natural forcing. It involves taking a vector of observed climate changes, such as warming rates in locations around the world, and decomposing them into a weighted sum of "signals", which are analogues to the observations generated by climate models with different types of forcings. The weights are chosen using a regression method called Total Least Squares. The analysis commonly uses just two signals, one generated by models using only anthropogenic forcings and one using only natural forcings. If the estimated weighting coefficient attached to a signal is significantly different from zero, then that signal is said to be "detected". If it is close to 1.0, then the model generating the signal is said to be consistent with observations. If it is less than 1.0, then the model signal for that forcing is too strong and needs to be scaled down, and vice-versa. Both the observed data and the signals are weighted using a model-generated estimate of patterns of randomness in the climate system so as, in principle, to put maximum weight on regions where natural variability is minimized.

Optimal fingerprinting is the primary tool for attribution in the climate literature. Studies applying it have been cited thousands of times, and it has been prominently featured by the IPCC since the 2001 Third Assessment Report. One of its inherent weaknesses is that results depend on assumptions about the accuracy of climate models, especially regarding their representation of natural variability (IPCC AR5 Ch 10.2.3).

Additionally, a series of papers by McKittrick (McKittrick 2022a, 2022b, 2023, 2025) has challenged the optimal fingerprinting method, arguing that it is inherently unreliable and that commonly used practices in econometrics can provide more valid results. Statistical theory requires that for regression models to yield unbiased coefficients, a set of assumptions called the Gauss-Markov conditions must hold. McKittrick (2022a) argued that the Allen and Tett (1999) methodology violates the Gauss-Markov conditions, leading to potentially biased and inconsistent

fingerprinting coefficients, undermining the reliability of the method. Chen et al. (2023) confirmed this analysis and argued that the method could yield unbiased results but only under very stringent assumptions. McKittrick (2022b) and (2023) raised a further concern that climate scientists—virtually alone among scientific disciplines—have used an estimation method called Total Least Squares (TLS) to estimate anthropogenic greenhouse gas signal coefficients, despite its tendency to be unreliable unless some strong assumptions hold that in practice are unlikely to be true. Under conditions which easily arise in optimal fingerprinting, TLS yields estimates with large positive biases. Thus, any study that has used TLS for optimal fingerprinting without verifying that it is appropriate in the specific data context has likely overstated the result.

McKittrick (2025) presented an empirical example comparing the results of conventional optimal fingerprinting against methods drawn from mainstream econometrics which are known to be valid for the specific application of signal detection. While the IPCC optimal fingerprinting method yields an anthropogenic signal coefficient close to 1.0 on a global temperature data set spanning 1900 to 2010, consistent estimation yields a coefficient around 0.4, which rises to about 0.65 on data spanning 1980 to 2010, implying the model response to greenhouse gases needs to be scaled down by about half to optimally match observations. The natural forcing signal coefficient, by contrast, is between 2.0 and 4.0, implying the climate model signals of natural forcing need to be scaled up two-to four-fold to match observed climate change. The fingerprinting coefficients estimated in McKittrick (2025), when used to scale the average sensitivity of the climate models used to generate the forcing signals in his data set, imply a Transient Climate Sensitivity of 1.4°C, which matches the estimate by Lewis (2022) using a different estimation method and multiple independent data sets.

While these analyses do not prove that all of the results from using the IPCC optimal fingerprinting method are wrong, it does show that the basis on which they were believed to be correct is non-existent – hence reducing confidence in the results.

7.3.3 Time series methods

The IPCC (AR5 WGI 10.2.2) drew attention to alternative approaches of assessing causality that emerged from the time series econometrics literature. They have the advantage of not depending on assumptions about the accuracy of climate models, but their disadvantage is they depend on assumptions about the data generating process underlying climate and forcing data that are not straightforward to test. The methods, now referred to as climate econometrics, use the tools of unit root testing, Granger causality and cointegration analysis, all of which are familiar in economics and finance and which are slowly being adopted in climate science. Time series analysis methods hold out the possibility of determining whether anthropogenic or natural forcings are the primary drivers of climate change without requiring the use of climate models, although key questions remain unsettled (e.g. Dergiades et al. 2016, Balcombe et al. 2019, Dagsvik et al. 2020, Razzak 2022, Dagsvik and Moen 2023).

Granger causality modeling is a tool for determining directions of influence in data series that move together. “Granger causality” is a statistical, not a physical, concept. If knowing the current value of one variable significantly improves the forecast accuracy of another variable we can infer a causal connection exists; this is called Granger causality. The modeling tools, called vector autoregression, measure direct impulse-response patterns and feedbacks. An application to

the well-known Vostok ice core data revealed an error by Al Gore in his documentary *An Inconvenient Truth*. Gore showed the data and drew attention to the coherence of temperature and CO₂ changes over a 440,000 year span, which he asserted was due to CO₂ driving temperature changes. But temperature changes can also affect atmospheric CO₂ levels. Davidson et al. (2015) examined the series and found that temperature Granger causes CO₂ but not the reverse. In other words on the time scales represented in the Vostok data the coherence in the series is primarily due to the influence of temperature on CO₂ levels not the feedback going from CO₂ to temperature.

In summary, the main statistical methods for attributing causation in climate data are optimal fingerprinting and time series analysis. Applications of the Allen and Tett (1999) optimal fingerprinting method dominate the attribution literature and have underpinned past IPCC conclusions, but results depend on the accuracy of climate models and the method has recently been criticized as inherently biased. Time series methods do not depend on climate models but require assumptions of their own and have generated results that have thus far not converged on a consensus.

7.4 Extreme event attribution (EEA)

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table 12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most regions in the mid-latitudes, medium confidence elsewhere
- Medium confidence in a decrease in extreme cold events in Australia, Africa and most of northern South America where observations allow trend estimation
- No evidence of emergence in the historical period of a change in river floods, heavy precipitation, drought, fire weather, severe wind storms, and tropical cyclones

While the overall issue of detecting changes in extreme weather events and their attribution remains ambiguous, most of the activity in this area relates to the attribution of single extreme weather events. The most prominent effort is the World Weather Attribution (WWA; worldweatherattribution.org), which is an international research initiative that focuses on extreme event attribution analyzing how climate change influences the likelihood and intensity of extreme weather events. The approach used by the WWA runs large ensembles of regional climate models

to compare the event in today's climate, versus a pre-industrial counterfactual climate without human-caused warming.

WWA plays a prominent role in linking extreme weather to climate change and its press releases attract considerable public and policy discussions. However, the WWA's tendency to promote non-peer-reviewed findings, funding ties, open admission that they shape their analyses to serve purposes of litigation and other methodological challenges have sparked controversies, with critics questioning the robustness and impartiality of its conclusions (Pielke Jr. 2024). Despite these issues, WWA's work continues to shape climate science and media narratives. Technical criticisms of the approach include: neglect of a formal detection process; an implicit assumption that 100% of the post-industrial warming is caused by CO₂; and failure to adequately account for natural internal climate variability.

Because EEA is relatively new many basic methodological issues have yet to be settled in the expert literature. An important challenge is the lack of data. Extreme events are by definition rare. Many analyses of extreme event types (including the US National Assessment Reports) only evaluate data since 1950 or 1970. However, as emphasized by Chapter 8, many of the worst extreme weather and climate events in U.S. history occurred prior to the first half of the 20th century including in the early 19th century. And if paleoclimate reconstructions are considered, it becomes very difficult for an event to pass the detection thresholds of exceeding what is expected from natural variability, particularly if a reasonably sized geographic region is considered.

Another challenge is defining the event under study. There is a longstanding literature in statistics and econometrics on the challenge of analyzing data with outliers. The issue arises because a data series establishes a probability distribution defining the expected range of observations. If an outlier is observed it might indicate that the underlying process giving rise to the data distribution has changed (which in the weather context would mean a climatic change has been detected) or that the underlying process has multiple regimes each with a different probability distribution, in which case observing an outlier simply means we were temporarily in a different regime, but the system itself was unchanged. If a time series contains only a single outlier event at the end of the series it is not possible to determine which model is the correct one (Chen and Liu 1993). For instance, there might be an "ordinary" weather regime that yields a distribution of summer daytime highs in a particular coastal region, and a second "heatwave" regime that kicks in when an inland blocking event occurs, which yields a temperature distribution centered 15°C higher than the first one. A day with temperatures 13°C above normal would either be an extreme heat anomaly under the first regime or a somewhat cool event under the second, and we have no way in this case of knowing on statistical grounds which view is correct.

Visser and Petersen (2012) and Sardeshmukh et al. (2015) both point out that different distributions may fit observed data equally well but yield very different implications about the likelihood of a specific weather event. Visser and Petersen argue that, in view of the deep uncertainties of extreme weather analysis drawing a connection between individual events and global climate change should be avoided. Furthermore the existence of an outlier at the end of a data series poses the problem that estimates of the event probabilities will be biased whether the outlier is included or excluded (Barlow et al. 2020). Methods to eliminate the bias have not yet been established, leading some experts (e.g. Miralles and Davison 2023) to argue that in settings in which a data series

contains a single extreme event at the end, estimation of a return period for the extreme event will be so biased and uncertain it should be avoided altogether.

In spite of these concerns, the U.S. is presently considering something like the WWA, which is being investigated by a NASEM Panel on Attribution of Extreme Weather and Climate Events and their impacts (NASEM, 2025).

A case studies from a recent high impact extreme events in the U.S. is provided to illustrate the challenges and ambiguities in attributing the frequency and intensity of extreme weather events to human-caused warming.

7.4.1 Case study – 2021 Western North America heat wave

The 2021 Western North America heat wave was an extreme heat wave that affected much of Western North America in late June 2021. In particular, surface temperature records were set in Portland, OR (116°F; previous record 107°F) and Seattle, WA (108 °F; previous record 103°F) (Mass et al., 2024).

The WWA team garnered international headlines for their analysis and provided the following attribution statements (WWA, 2021; Philip et al., 2022):

- Based on observations and modeling, the occurrence of this heatwave was virtually impossible without human-caused climate change.
- The event is estimated to be about a 1 in 1000-year event in today's climate.
- The event would have been at least 150 times rarer without human-induced climate change.
- This heatwave was about 2°C hotter than it would have been if it had occurred at the beginning of the industrial revolution (when global mean temperatures were 1.2°C cooler than today).

But an important caveat to the first claim is that other researchers concluded, based on historical weather data, that while a heat wave of the magnitude observed was indeed virtually impossible without anthropogenic climate change, it was also virtually impossible *with* climate change. Bercos-Hickey (2022) noted “these temperatures were virtually impossible under any previously experienced meteorological conditions, with or without global warming.” McKinnon and Simpson (2022) stated “the most likely explanation remains that the weather event itself was ‘bad luck.’” The 2023 Oregon Climate Assessment (Fleischman 2023) concluded that the heat dome would have formed even without climate change and “There is no evidence that the highly unusual combination of weather features that drove the heat dome were made more likely by climate change, and climate models do not project an increase in the frequency of high-pressure ridges over the Pacific Northwest” (Fleischman 2023 p. 49).

Mass et al. (2024) summarizes the proximate sequence of compound events leading to the heat wave. There was a record-breaking midtropospheric ridge over the Pacific Northwest, forced by a tropical disturbance in the western Pacific. This produced record-breaking midtropospheric temperatures, strong subsidence in the lower atmosphere, low-level easterly flow that produced downslope warming on regional terrain and the removal of cooler marine air, and an approaching

low-level trough that enhanced downslope flow. The event occurred at a time of maximum solar insolation, and drier-than-normal soil moisture. Using a storyline approach, Mass et al. assessed that there is no trend in drought and dry soils in the Pacific Northwest; there is no evidence of global warming producing stronger ridges of high pressure, and no observed trend in heat waves or record temperatures in the region. They concluded that although anthropogenic warming may have contributed as much as 2°F to the magnitude of the event, there is little evidence of further amplification of the event from increasing greenhouse gases.

A statistical analysis of a model-based attribution study of this heat wave was conducted by Bercos-Hickey et al. (2022). Because this event is a far outlier and far above the bounds of Generalized Extreme Value distributions fitted from historical data, they concluded that estimates of return times, quantitative changes in event magnitude and frequency, and probability of the extreme temperatures such as provided by the WWA are not accurate and should be interpreted as having low confidence. They found that hindcast attribution methods using an ensemble of regional climate models, combined with Pearl (2009) causal inferences, can provide limited and conditional information about the magnitude of the human influence on this heatwave – they provided a more highly constrained estimate that human activities caused a ~1.4°C–1.8°F increase in the daily maximum temperatures.

Zeder et al. (2023) also concluded that the methods employed by Philip et al. (2022) tend to overstate the rarity of extreme heat waves, leading to a biased perception of the effect of climate change on the heatwave event: “The tendency to overestimate the return period of observed extreme heatwave events may fuel the impression that seemingly impossible heatwave extremes are currently clustering at an unprecedented rate.”

The 2021 Western North America heatwave was a rare and unprecedented compound weather event, that broke century-old temperature records by as much as 9°F. While the WWA team received worldwide publicity for their rapid attribution claims blaming anthropogenic climate change, subsequent peer-reviewed analysis showed that the rare event was not made more probable by global warming.

7.5 Summary

There is an ongoing scientific debate around attribution methods, particularly in attributing extreme weather events to climate change. The IPCC has long cautioned that methods to establish causality in climate science are inherently uncertain and ultimately depend on expert judgement.

There are two areas of substantive criticism of the IPCC assessment of the causes of the recent warming: inadequate assessment of natural climate variability, and inappropriate statistical methods.

Detection of extreme weather events is challenged by their rarity, requiring a long data set and a choice of region and spatial scale to evaluate their occurrence against the background of natural weather and climate variability.

The most robust attribution statements for an extreme event relate to an incremental change (e.g. a temperature change in degrees or percent change in rainfall). Statements related to return times, quantitative changes in event magnitude and frequency, and probability of the extremes are not accurate owing to an inadequate amount of data, and are made with low confidence. There is no evidence in a change of weather or climate regime patterns from increasing greenhouse gases that would amplify or dampen extreme weather events, beyond basic thermodynamic considerations.

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From: Judith Curry [curry.judith@gmail.com]
Sent: 5/9/2025 6:39:16 PM
To: Steven Koonin [steven.koonin@gmail.com]
CC: Roy Spencer [roywspencer@hotmail.com]; John Christy [climateman60@gmail.com]; Ross McKittrick [ross.mckittrick@gmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]
Subject: Re: attribution chapter

OOPs, previous email is the climate sensitivity chapter.

New attribution chapter coming in next email

On Fri, May 9, 2025 at 11:34 AM Steven Koonin <steven.koonin@gmail.com> wrote:

Judy – your email text says “attribution chapter” but you attached chapter 5 (climate sensitivity). Can you straighten out the confusion?

SEK

From: Judith Curry <curry.judith@gmail.com>
Sent: Friday, May 9, 2025 12:27 PM
To: Roy Spencer <roywspencer@hotmail.com>; John Christy <climateman60@gmail.com>; Steve Koonin <steven.koonin@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Subject: attribution chapter

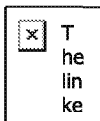
Latest version of attribution chapter is attached, Ross and I have hashed through this pretty thoroughly, we look forward to your comments

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From: Steven Koonin <steven.koonin@gmail.com>
Sent: Friday, May 9, 2025 2:34 PM
To: 'Judith Curry'; 'Roy Spencer'; 'John Christy'; 'Ross McKittrick'; 'Travis Fisher'
Subject: RE: attribution chapter
Attachments: ~WRD3204.jpg

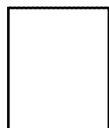
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Subject: attribution chapter

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From: Judith Curry [curry.judith@gmail.com]
Sent: 5/9/2025 4:26:41 PM
To: Roy Spencer [roywspencer@hotmail.com]; John Christy [climateman60@gmail.com]; Steve Koonin [steven.koonin@gmail.com]; Ross McKittrick [ross.mckittrick@gmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]
Subject: attribution chapter
Attachments: 5 Climate SensitivityMay09.docx

Latest version of attribution chapter is attached, Ross and I have hashed through this pretty thoroughly, we look forward to your comments

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5 Climate Sensitivity to CO₂ Forcing

5.1 Introduction

The sensitivity of Earth's climate to increasing concentrations of CO₂ is at the heart of the scientific debate on anthropogenic climate change, and also the public debate on the appropriate policy response to increasing CO₂ in the atmosphere. Equilibrium Climate Sensitivity (ECS) refers to the expected amount of warming averaged over the Earth's surface in response to a doubling of CO₂, after all climate systems have had time to adjust. Some systems, like temperatures in the troposphere, adjust very rapidly, whereas others such as the deep ocean and ice sheets may take decades or even centuries. A related metric which is helpful for analysis on shorter time scales is the Transient Climate Response (TCR), defined as the amount of warming after 70 years in which atmospheric CO₂ increases by one percent annually.

In 1979 the Charney (1979) Report for the US National Academy of Sciences proposed that the most likely value for ECS was 3.0°C plus or minus 1.5°C. The ECS range between 1.5 and 4.5°C is characterized by the IPCC AR5 as the *likely* range (66 percent probability); the AR5 stated that ECS is *extremely unlikely* (95 percent probability) to be below 1.0°C and very unlikely (90 percent probability) to exceed 6.5°C. This range of ECS values has remained stubbornly wide, despite many individual studies claiming to narrow it. Most recently, the IPCC AR6 narrowed its assessment of the *likely* range of ECS to 2.5–4.0°C and the *very likely* range to be between 2.0 and 5.0°C. This narrowing of the range on the low end is disputed, as will be discussed below.

Uncertainties about ECS are highly consequential for policy making. As will be discussed in Chapter 13, economic models take the ECS value from climate science and use it to project the costs of CO₂ emissions. The traditional ECS value (3.0 °C) has typically yielded modest global social costs of CO₂ emissions, enough to justify some policy actions though mostly deferred to later in the century. If ECS is very high (4.5°C or above) aggressive immediate emission controls become more imperative, whereas values closer to 2.0°C have been shown to imply that no CO₂ emission controls are economically justifiable (Dayaratna et al. 2016, 2020). Obtaining a precise estimate is impossible, so policy making needs to account for the uncertainty.

5.2 Model-based methods of computing climate sensitivity to GHGs

The ECS ranges for the IPCC AR4 and AR5 were obtained primarily by examining the behaviour of climate models. For the AR6 the IPCC changed course and turned to a more direct data-driven methodology. Here we discuss some of the pitfalls of using climate models to try to determine the Earth's climate sensitivity.

ECS represents an emergent property of climate models—that is, it is not directly parameterized or tuned. However, collections of parameterizations are often chosen to produce an expected value of climate sensitivity, particularly with regards to sub-grid-scale cloud processes. Otherwise plausible models and parameter selections have been discarded because of perceived conflict with this warming rate, or aversion to a model's climate sensitivity being outside an accepted range. For example, Mauritsen and Roeckner (2020) state the following regarding their Max Planck Institute climate model (emphasis added):

“We have documented how we tuned the MPI-ESM1.2 global climate model to match the instrumental record of warming; an endeavor which has clearly been successful. Due to the

historical order of events, the choice was to do this practically by *targeting an ECS of about 3 K using cloud feedbacks*, as opposed to tuning the aerosol forcing.”

In other words, the modelers chose an ECS value of 3°C and then tuned the cloud parameterizations to match their intended result.

Direct warming from CO₂ doubling is only about 1°C (Hall and Manabe 1997); further warming arises from climate feedbacks that are not explicitly resolved by the model but rely on parameterizations of physical processes. Higher values of ECS arise primarily from positive cloud feedbacks whose magnitude and even sign are very uncertain. Elements of cloud feedback include changes in the latitudinal distribution of clouds, changes in the distribution of cloud height (changes in low versus high clouds), changes to the phase of clouds (ice versus liquid), changes in cloud particle size (associated with changes in concentration and/or composition of aerosol particles), changes in the precipitation efficiency of clouds, and even changes in how clouds are distributed over the daily solar cycle (Curry and Webster, 1999). It is difficult for climate models to simulate any of these processes correctly owing to their small scale, let alone predict how they will change in the future. Further, cloud processes modulate the magnitudes of the water vapor, lapse rate, and the surface albedo feedbacks.

ECS can be determined from climate model simulations by doubling the concentration of CO₂ and allowing several centuries for the warming to equilibrate. To avoid the necessity of long simulations, “effective climate sensitivity” is commonly evaluated from a 150-year simulation in response to a sudden quadrupling of CO₂. The spread of ECS values from the CMIP5 climate models (used in the AR5) was 2.0–4.7°C; the spread has increased for the CMIP6 models (used in the AR6) to between 1.8 and 5.7°C (Chen et al, 2021). Far from the science being settled in relation to the response of the climate system to increasing greenhouse gas concentrations, insofar as it is represented by climate models, uncertainties appear to be growing. The main cause of the overall upward shift in ECS in CMIP6 relative to CMIP5 is a larger positive cloud feedback, driven by changes to the cloud parameterizations in many CMIP6 models (Zelinka et al., 2020)

Because of concerns about model tuning and the high sensitivity to cloud parameterizations, the IPCC AR6 (2021) did not rely on climate model simulations in their assessment of climate sensitivity, relying instead on other methods in its assessment instead, chiefly a recent empirical estimate.

5.3 Data-driven methods of computing climate sensitivity to GHGs

Climate sensitivity can also be estimated from instrumental records of surface temperatures and ocean heat content, combined with estimates of how climate forcings (e.g., greenhouse gases, solar, volcanoes, aerosols) have changed in the past (Otto et al., 2013). Using this information, a simple empirical model called an Energy Balance Model can be estimated. It requires estimating a feedback parameter whose uncertainties are highly amplified in the resulting ECS (Roe and Baker, 2007).

The accuracy of the data-driven methods depends on the quality of the input data. Assumptions are needed about ocean heat storage, and the ocean data is inadequate. The greatest source of uncertainty is the amount and composition of aerosol particles and their interactions with cloud radiative properties (the so-called aerosol indirect effect). Climate models exhibit warming in response to GHGs but cooling in response to aerosols (Schwartz et al. 2007). Observed 20th century warming can be shown to be consistent either with low ECS and low aerosol cooling, or high ECS and high aerosol cooling. Since fossil fuel use adds both GHGs and aerosols to the atmosphere, both effects

need to be estimated to isolate the warming effect of CO₂. Over time, the IPCC's estimate of the cooling effect of aerosols has declined (Lewis 2022).

Paleoclimate proxies are also used to evaluate the sensitivity of past climates, by comparing paleoclimate changes in the Earth's temperatures to estimates of changes in forcings. The two most informative periods are the last glacial maximum (around 20,000 years ago), which was about 3–7°C colder than today, and a mid-Pliocene period (roughly three million years ago), which was 1–3°C warmer than today. The limits on cooling during the last glacial maximum give the best single evidence that high values of climate sensitivity are unlikely. However, paleoclimate estimates are associated with very large uncertainties in the estimated temperatures and forcings. Further, estimates of climate sensitivity based on past climate states may not be representative of the current state of the climate system.

A recurring theme in the climate literature is that ECS estimates based on historical data are smaller than ECS estimates inferred from climate models (Sherwood and Forest 2024). About 15 estimates based on historical data appeared in the peer-reviewed literature between 2012 and 2024 yielding ECS best estimates between 1.0°C and 2.5°C, although critics have questioned some of the methods and the data quality. For the AR6, the IPCC placed primary weight on the results of Sherwood et al. (2020) that combined historical and paleoclimate proxies and yielded a best estimate of 3.1°C. Lewis (2022) raised a number of concerns about this result, including methodological errors, outdated input values, and use of subjective versus objective Bayesian priors in the analysis. Lewis' analysis found that climate sensitivity is estimated to be much lower and better constrained than in the Sherwood et al. analysis – median 2.2°C (1.8–2.7°C in the 17–83 percent *likely* range, and 1.6–3.2°C in the 5–95 percent *very likely* range). The IPCC AR6 estimated only a 5 percent probability that ECS was below 2.3°C, whereas Lewis estimated it to be over 50 percent. The most recent publications on the debate between Sherwood et al. and Lewis further defend their respective positions: Sherwood and Foster (2024) and Lewis (2025).

An interesting footnote is that in 1983, the US National Research Council conducted a follow-up study to the 1979 Charney Report, and referring to the estimated sensitivity range of 1.5°C to 4.5°C, said:

“The climate record of the past hundred years and our estimates of CO₂ changes over that period suggest that values in the lower half of this range are more probable.”
Nierenberg et al. (1983 p. 2)

Lewis' analysis likewise implies that climate sensitivity is likely in the lower half of the original 1979 Charney range.

A recent argument, which the IPCC AR6 emphasized, is that data-driven ECS estimates might understate the future warming response to GHGs based on a so-called “pattern effect” (Forster et al 2021). The tropical Pacific is believed to be highly influential on the overall efficiency with which the Earth's climate radiates heat to space, but in some regions heat is more efficiently removed from the climate system than from others. If in a warming climate there is a weakening of the west-to-east temperature gradient in the tropical Pacific, the result would be a concentration of warming in a region where heat is less efficiently removed, raising the ECS of the Earth's climate system. Most climate models simulate that rising GHGs will weaken the east-west temperature gradient, which led the IPCC in the AR6 to conclude that data-driven ECS estimates understated the *future* ECS value.

However, Seager et al. (2019) pointed out that, contrary to models, the east-west temperature gradient has been strengthening rather than weakening over time. They further argued that the

mechanism predicting otherwise in climate models was based on a faulty characterization of oceanic dynamics and there is no reason to expect the gradient to weaken. A similar argument was recently made by Lee et al. (2024), who concluded that “the trajectory of the observed trend reflects the response to increasing GHG loading in the atmosphere”; in other words, GHG warming should lead to a future strengthening rather than a weakening of the temperature gradient. Increased efficiency of atmospheric cooling implies, if anything, that the future ECS in a warming climate may be *lower* than current estimates.

5.5 Transient Climate Response

The Transient Climate Response (TCR) is of greater utility in providing an observational constraint on climate sensitivity. TCR is the amount of warming that would occur at the time when CO₂ doubles, having increased gradually by 1 percent each year over a period of 70 years. Relative to the ECS, observationally-determined values of TCR avoid the problems of uncertainties in ocean heat uptake and the fuzzy boundary in defining equilibrium arising from a range of timescales for the longer-term feedback processes (e.g., ice sheets). TCR is more generally related to peak warming and better constrained by historical warming, than ECS. The IPCC AR6 judged the *very likely* range of TCR to be 1.2–2.4°C. In contrast to ECS, the upper bound of the TCR is more tightly constrained. For comparison, the TCR values determined by Lewis (2023) is 1.25 to 2.0°C, showing much better agreement with the AR6 values than was seen in a comparison of the ECS values.

A related but more flexible parameter is the Transient Response to cumulative carbon Emissions, or TCRE, which relates global temperature change to the cumulative emissions. TCRE is based upon a linear relationship between global average temperature and cumulative emissions, which holds for cumulative emissions of up to 2 teratons of carbon. For a given value of TCRE, we can estimate the amount of warming expected over a future period in response to scenarios of cumulative carbon emission. The IPCC AR6 provides a *very likely* range for TCRE of 1.0–2.3°C, with a median value of 1.6°C.⁴⁸

As will be discussed in Chapter 6, a real-world ECS below the model average is supported by studies which show climate models on average estimate too much warming at the surface and in the troposphere compared to observations over the past 50 years. Also, lower values align with evidence from consistent fingerprinting (Section 8) that model responses to GHGs need to be scaled down quite a bit to align with observed trends.

5.6 Summary

In the past 5 years, there is a growing realization that climate models are not fit for the purpose of determining the sensitivity of the climate to increasing CO₂ (ECS), owing to the dependence of this sensitivity on poorly resolved processes related to clouds and water vapor.

Data-driven approaches using historical data and paleoclimate reconstructions are now regarded as more reliable for determining ECS, but their reliability is diminished by data inadequacies. The IPCC AR6 upper bound for the *likely* range of ECS is 4.0°C, lower than the AR5 value of 4.5°C. This lowering of the upper bound seems well justified by the paleoclimatic estimates of the ECS. The IPCC AR6 lower bound for the *likely* range of ECS is 2.5°C, substantially higher than the AR5 value of 1.5°C. This raising of the lower bound of the likely range of ECS has received a substantial challenge from the analysis of Lewis (2022, 2025) that finds the lower bound of the likely range to be 1.75°C with a

median value of 2.2°C. Other lines of evidence supporting a lower bound on the ECS range below the IPCC AR6 value are discussed in Chapters 6 and 7.

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From: Ross McKitrick <ross.mckitrick@gmail.com>
Sent: Wednesday, May 14, 2025 2:04 PM
To: Steven Koonin
Cc: Judith Curry; Roy Spencer; Travis Fisher; John Christy
Subject: Re: my edits to Chapter 7 attached

Steve I put your version in the DB folder after renumbering it as Ch 9.

On Wed, May 14, 2025 at 1:49 PM Ross McKitrick <ross.mckitrick@gmail.com> wrote:

It will be inevitable at this point that revised drafts start to cross in flight. I'll do my best to keep track of them and keep the dropbox current. As long as everyone makes sure that the documents you circulate have names that clearly indicate the version we should be ok.

On Wed, May 14, 2025 at 1:37 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Given John's recent email distributing his edits to this chapter, we're starting to have version control problems

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Steve Koonin

From: Steven Koonin [steven.koonin@gmail.com]
Sent: 5/14/2025 5:37:06 PM
To: 'Ross McKittrick' [ross.mckittrick@gmail.com]
CC: 'Ross McKittrick' [ross.mckittrick@gmail.com]; 'Judith Curry' [curry.judith@gmail.com]; 'Roy Spencer' [roywspencer@hotmail.com]; 'Travis Fisher' [travis.scott.fisher@gmail.com]; 'John Christy' [climatemanager60@gmail.com]
Subject: my edits to Chapter 7 attached
Attachments: 7 Attribution.[RM].May11[SEK].docx

Given John's recent email distributing his edits to this chapter, we're starting to have version control problems

Steve Koonin

7 Uncertainties in Climate Change Attribution

7.1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) distinguishes between detection of climate change and attribution of its cause.¹ As defined by the IPCC AR6 WGI Glossary (IPCC, 2025):

Detection: “Detection of change is defined as the process of demonstrating that climate or a system affected by climate has changed in some defined statistical sense, without providing a reason for that change. An identified change is detected in observations if its likelihood of occurrence by chance due to internal variability alone is determined to be small, for example, <10%.”

Attribution: “Attribution is defined as the process of evaluating the relative contributions of multiple causal factors to a change or event with a formal assessment of confidence.”

Both steps rely on statistical analysis. Detection focuses on whether changes are significant enough to stand out from random variation regardless of cause. Attribution involves comparison of observed events to model-generated counterfactuals. Since experimentation on the climate is not possible, attribution requires statistical inference to assess how much human activities, such as GHG emissions, versus natural factors, like volcanic eruptions, contribute to observed changes. Attribution methods assume all external and internal drivers of the system are known and represented.

There are ongoing scientific debates around attribution methods, especially for attributing extreme weather events to climate change. The IPCC has long cautioned that methods to establish causality in climate science are inherently uncertain and ultimately depend on expert judgement. The Fourth Assessment Report: The Physical Science Basis (Hegerl et al., 2007) explained it as follows:

‘Attribution’ of causes of climate change is the process of establishing the most likely causes for the detected change with some defined level of confidence... unequivocal attribution would require controlled experimentation with the climate system. Since that is not possible, in practice attribution of anthropogenic climate change is understood to mean demonstration that a detected change is ‘consistent with the estimated responses to the given combination of anthropogenic and natural forcing’ and ‘not consistent with alternative, physically plausible explanations of recent climate change that exclude important elements of the given combination of forcings’ (IPCC, 2001)... The approaches used in detection and attribution research described above cannot fully account for all uncertainties, and thus ultimately expert judgement is required to give a calibrated assessment of whether a specific cause is responsible for a given climate change.

The Fifth Assessment Report Working Group II makes the following statement:

¹ Note that the IPCC definition of “climate change” allows for both natural and human causes. This differs from the UNFCCC definition (and common usage), where the term is limited to human causes.

(Cramer et al., 2014):

“Two broad challenges to the detection and attribution of climate change impacts relate to observations and process understanding. On the observational side, high-quality, long-term data relating to natural and human systems and the multiple factors affecting them are rare. In addition, the detection and attribution of climate change impacts requires an understanding of the processes by which climate change, in conjunction with other factors, may affect the system in question.”

Because of the complexity of the causal chains in the climate system, investigation of these relationships is exceptionally challenging.

7.2 Attribution methods

The Intergovernmental Panel on Climate Change (IPCC) employs several attribution methods to assess the causes of observed climate changes, distinguishing between natural and human-induced factors. Below is a concise description of the key methods that have been used by the IPCC:

Optimal Fingerprinting uses linear regression to explain variations in observed climate data as a weighted sum of climate model simulations run with and without anthropogenic forcings. The data used in the regression model are weighted to try to minimize the influence of random noise and the estimation method is chosen to take account of climate model error.

Time Series Analysis exploits statistical differences between anthropogenic forcing and natural variability to see which dominates observed temperatures, and also uses variations in the timing of changes to determine if causal dependence across data series can be inferred.

Process-Based Attribution focuses on understanding the physical mechanisms behind observed changes. This approach combines observations, climate models, and theoretical understanding to attribute changes in specific processes to forcings. This approach is often used for regional climate phenomena, such as monsoon changes or polar amplification

Extreme Event Attribution assesses in the role of human influence in the likelihood of occurrence or intensity of extreme weather events (e.g. heat waves, droughts). Methods include:

- Probabilistic Event Attribution uses large ensembles of climate model simulations to compare observed events to model-generated counterfactuals
- Storyline Approach examines the physical processes driving an event and evaluates how anthropogenic forcings may have modified those processes

7.3 Attribution of global warming

Attribution statements for global warming in the three most recent IPCC Assessment reports are:

AR4: “Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.” (IPCC, 2007)

AR5: “It is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together. The best estimate of the human- induced contribution to warming is similar to the observed warming over this period.” (IPCC, 2013)

AR6: “The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.” (IPCC, 2021)

The AR4 and AR5 attribution statements reference the warming since the mid-20th century, the period when greenhouse gas emissions began rapidly increasing. The words “most” and “more than half” are deliberately imprecise, potentially ranging from 51 to 99% of the warming – presumably this imprecision is to account for structural uncertainties such as natural internal variability. The confidence level increases from *very likely* to *extremely likely* from AR4 to AR5. The structure of the attribution statement in the AR6 is fundamentally different, referencing the warming to the period 1850-1900. The AR6 attribution statement is more precise numerically, but with a lower level of confidence at “likely” – the AR6 attributes essentially all the warming to increases in greenhouse gases. The most confident statement from the AR6 relates to the tropospheric warming since 1979, using the words “main driver” and “*very likely*.”

There are three areas of substantive criticism of the IPCC’s assessment of the causes of the recent warming: inadequate assessment of natural climate variability, inappropriate statistical methods, and substantial discrepancies between models and observations. The last is discussed in Chapter 6, while this chapter discusses the first two factors. All of these criticisms are relevant to the IPCC’s policy-informing attribution of the recent warming, which also underpins extreme event attribution

7.3.1 Natural climate variability

IPCC AR6 states that natural external drivers since 1850-1900 have changed global surface temperature by –0.1°C to +0.1°C, and internal variability has changed it by –0.2°C to +0.2°C – on average having essentially no net impact on the warming since 1850-1900. This minimal contribution of natural variability has been disputed by a number of publications that question the magnitudes of solar variability and internal variability from the large-scale ocean circulations (R Connolly et al., 2021; W Soon, 2023).

If the Equilibrium Climate Sensitivity to CO₂ is low (Chapter 5), then natural climate variability becomes more important in the attribution of the recent warming. Further, if natural variability is higher, then estimates of the Equilibrium Climate Sensitivity from the historical period would be lower (Scafetta, 2023).

Solar variability

IPCC AR5 concluded that the best estimate of radiative forcing due to Total Solar Irradiance (TSI) changes over the period 1750–2011 was 0.05 W/m² (Myrhe et al., 2014). IPCC AR6 acknowledges a much larger range of estimates of changes in TSI over the last several centuries, stating that the TSI between the Maunder Minimum (1645–1715) and the second half of the twentieth century increased by 0.7–2.7 W/m², a range that includes both low and high variability TSI data sets (Gulev, 2021). However, the recommended forcing dataset for the CMIP6 climate model simulations used in AR6 for attribution studies averages two data sets with low solar variability (Matthes, 2017).

While AR6 shows a substantially greater solar impact than does AR5, the overall impact on the climate was assessed to be small compared to anthropogenic forcing of climate change. However, the impact of solar variations on the climate is uncertain and subject to substantial debate – something that is not evident from the IPCC assessment reports (Lockwood, 2012; Connolly et al., 2021).

Exactly how TSI has changed over time has been a challenging problem to resolve. Since 1978, there have been direct measurements of TSI from satellites. However, the data exhibit non-negligible inconsistencies, and interpreting any multi-decadal trends in TSI requires comparisons of observations from overlapping satellites. There are several rival composite TSI datasets, disagreeing as to whether TSI increased or decreased during the period 1986–96 (the ACRIM gap; see Chapter 4). Further, the satellite record of TSI is used for calibrating proxy models, whereby past solar variations are inferred from sunspots and cosmogenic isotope measurements (Velasco Herrera et al., 2015).

There is substantial evidence for high solar activity in the second half of the 20th century (starting in 1959) and extending into the 1990's, before a decline in the early 21st century; this period is often termed the “Modern Maximum.” (Chatzistergos et al., 2023; Solanki et al., 2004; Usoskin et al., 2007). However, some scientists have concluded that it is not possible to be confident of any multi-decadal trend in TSI (Schmutz, 2021).

As a result of this uncertainty, some reconstructions for past values of TSI (since 1750) have low variability, implying a very low impact of solar variations on global mean surface temperature, whereas datasets with high TSI variability can explain more than 70% percent of the temperature variability since preindustrial times (Scafetta, 2013; Stefani, 2021). Hence, the choice of which TSI satellite record used in an analysis can substantially influence how much climate change is attributed to human versus natural forcings.

There is growing evidence that other aspects of solar variability, which are referred to as solar indirect effects, amplify TSI forcing or are independent of TSI forcing. Scafetta et al. (2023)

suggests that ~80% of solar influence on climate may stem from non-TSI mechanisms. Candidate processes include: solar ultraviolet changes; energetic particle precipitation; atmospheric-electric-field effect on cloud cover; cloud changes produced by solar-modulated galactic cosmic rays; large relative changes in the magnetic field; and the strength of the solar wind. Solar indirect effects are not included in climate models, although indirect methods of estimating these effects suggest significant influence. However, claims of non-TSI mechanisms influencing climate are uncertain and debated.

Natural variability of large-scale ocean circulations

Variations in global mean surface temperature are linked to recurrent large-scale variations in ocean circulation patterns. These circulation patterns include the Atlantic Multidecadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO) and the El Nino-Southern Oscillation (ENSO). These circulation patterns influence ocean heat uptake and heat distribution, and also influence atmospheric circulation patterns and cloud distributions. There is some debate as to whether these variations are strictly internal to the climate system, or whether this variability can have a solar/astronomical origin or can be influenced by large volcanic eruptions.

While climate models simulate the large-scale ocean circulations and internal climate variability, the simulated magnitude in the multi-decadal band is too low in most models relative to observations, and the phasing of the variability in long-term climate simulations is not synced with the actual, observed climate variations (Kravtsov et al. 2024). Averaging multiple simulations from climate models effectively averages out the internal variations, leaving only the forced climate variability (e.g., CO₂ forcing). With most of the modern warming beginning in the late 1970's, the recent 50-year warming is on the same time scale as the multi-decadal oscillations of the AMO and PDO.

Here are summary statements from the IPCC AR5 and AR6 reports:

“Decadal variability in the Pacific, associated with the PDO or IPO, contributes significantly to regional and global temperature trends, but the relative contributions of internal variability and external forcing are difficult to disentangle in CMIP5 simulations.” (IPCC, 2013)

"Since AR5, there has been increased understanding of the role of internal variability, such as ENSO, PDO, and AMO, in modulating regional climate trends. However, limitations in simulating the exact timing and amplitude of these modes in CMIP6 models contribute to uncertainties in attributing observed changes to anthropogenic forcing (high confidence)." (IPCC, 2021)

The amplitude of the peak-to-trough impact of the multi-decadal oscillations on global temperatures has been assessed by the IPCC AR6: “The likely range of change due to internal variability is -0.2°C to +0.2°C (IPCC, 2021).” This implies a trough-to-peak change of 0.4°C. Over many centuries, any global temperature changes from the troughs and peaks will cancel out, with little to no net impact.

However, with a nominal timescale of 60-80 years for oscillations such as the AMO and PDO, the timing of the peaks and troughs can be confused with the secular trend. This becomes very relevant for attributing the warming for the 50 years since 1975, during which most of the warming has occurred. Even if climate models have the correct amplitude of the multidecadal oscillations, the timing of the peaks and troughs is not adequately simulated, with each model and individual ensemble simulating a different phasing. Once the simulations of the ensemble members and different models are averaged, the natural internal variability contribution is averaged out, effectively cancelling the role of natural internal variability in the attribution process.

The Great Pacific Climate Shift of 1976-1977 was a notable climatic event characterized by an abrupt change in the North Pacific Ocean's atmosphere-ocean system that interacted with global climate patterns. This shift is closely associated with the Pacific Decadal Oscillation (PDO) that oscillates between warm and cool phases over decades. The 1976 shift marked a transition from a predominantly negative (cool) PDO phase (1947–1976) to a positive (warm) phase (1977 through 2000), with significant implications for global and regional climate patterns including the frequencies of El Niño and La Niña events. The Great Pacific Climate Shift coincided with the beginning of a period of accelerated global warming (REF TO A FIG OF GLOBAL TEMP ANOMALIES ELSEWHERE IN DOC) When the Great Pacific Climate Shift is accounted for in climate attribution analyses since 1950, it has been found that 40 percent or more of the warming in the second half of the 20th century was caused by natural internal variability (McLean et al., 2009; Tung and Zhou, 2013; Chylek et al., 2016; Scafetta, 2021).

7.3.2 Optimal fingerprinting

Optimal fingerprinting is a statistical technique introduced by Allen and Tett (1999) that compares observed climate data to climate model simulations to identify patterns (or "fingerprints") associated with human or natural forcing. It involves taking a vector of observed climate changes, such as warming rates in locations around the world, and decomposing them into a weighted sum of "signals", which are analogues to the observations generated by climate models with different types of forcings. The weights are chosen using a regression method called Total Least Squares. The analysis commonly uses just two signals, one generated by models using only anthropogenic forcings and one using only natural forcings. If the estimated weighting coefficient attached to a signal is significantly different from zero, then that signal is said to be "detected". If it is close to 1.0, then the model generating the signal is said to be consistent with observations. If it is less than 1.0, then the model signal for that forcing is too strong and needs to be scaled down, and vice-versa. Both the observed data and the signals are weighted using a model-generated estimate of patterns of randomness in the climate system so as, in principle, to put maximum weight on regions where natural variability is minimized.

Optimal fingerprinting is the primary tool for attribution in the climate literature. Studies applying it have been cited thousands of times, and it has been prominently featured by the IPCC since the 2001 Third Assessment Report. One of its inherent weaknesses is that results depend on assumptions about the accuracy of climate models, especially regarding their representation of natural variability (IPCC AR5 Ch 10.2.3).

Additionally, a series of papers by McKittrick (McKittrick 2022a, 2022b, 2023, 2025) has challenged the optimal fingerprinting method, arguing that it is inherently unreliable and that commonly used practices in econometrics can provide more valid results. Statistical theory requires that for regression models to yield unbiased coefficients, a set of assumptions called the Gauss-Markov conditions must hold. McKittrick (2022a) argued that the Allen and Tett (1999) methodology violates the Gauss-Markov conditions, leading to potentially biased and inconsistent fingerprinting coefficients, undermining the reliability of the method. Chen et al. (2023) confirmed this analysis and argued that the method could yield unbiased results but only under very stringent assumptions. McKittrick (2022b) and (2023) raised a further concern that climate scientists—virtually alone among scientific disciplines—have used an estimation method called Total Least Squares (TLS) to estimate anthropogenic greenhouse gas signal coefficients, despite its tendency to be unreliable unless some strong assumptions hold that in practice are unlikely to be true. Under conditions which easily arise in optimal fingerprinting, TLS yields estimates with large positive biases. Thus, any study that has used TLS for optimal fingerprinting without verifying that it is appropriate in the specific data context has likely overstated the result.

McKittrick (2025) presented an empirical example comparing the results of conventional optimal fingerprinting against methods drawn from mainstream econometrics which are known to be valid for the specific application of signal detection. While the IPCC optimal fingerprinting method yields an anthropogenic signal coefficient close to 1.0 on a global temperature data set spanning 1900 to 2010, consistent estimation yields a coefficient around 0.4, which rises to about 0.65 on data spanning 1980 to 2010, implying the model response to greenhouse gases needs to be scaled down by about half to optimally match observations. The natural forcing signal coefficient, by contrast, is between 2.0 and 4.0, implying the climate model signals of natural forcing need to be scaled up two-to four-fold to match observed climate change. The fingerprinting coefficients estimated in McKittrick (2025), when used to scale the average sensitivity of the climate models used to generate the forcing signals in his data set, imply a Transient Climate Sensitivity of 1.4°C, which matches the estimate by Lewis (2022) using a different estimation method and multiple independent data sets.

While these analyses do not prove that all of the results from using the IPCC optimal fingerprinting method are wrong, it does show that the basis on which they were believed to be correct is non-existent – hence reducing confidence in the results.

7.3.3 Time series methods

The IPCC (AR5 WGI 10.2.2) drew attention to alternative approaches of assessing causality that emerged from the time series econometrics literature. They have the advantage of not depending on assumptions about the accuracy of climate models, but their disadvantage is they depend on assumptions about the data generating process underlying climate and forcing data that are not straightforward to test. The methods, now referred to as climate econometrics, use the tools of unit root testing, Granger causality and cointegration analysis, all of which are familiar in economics and finance and which are slowly being adopted in climate science. Time series analysis methods hold out the possibility of determining whether anthropogenic or natural forcings are the primary drivers of climate change without requiring the use of climate models, although key questions remain unsettled (e.g. Dergiades et al. 2016, Balcombe et al. 2019, Dagsvik et al. 2020, Razzak 2022, Dagsvik and Moen 2023).

Granger causality modeling is a tool for determining directions of influence in data series that move together. “Granger causality” is a statistical, not a physical, concept. If knowing the current value of one variable significantly improves the forecast accuracy of another variable we can infer a causal connection exists; this is called Granger causality. The modeling tools, called vector autoregression, measure direct impulse-response patterns and feedbacks. An application to the well-known Vostok ice core data revealed an error by Al Gore in his documentary *An Inconvenient Truth*. Gore showed the data and drew attention to the coherence of temperature and CO₂ changes over a 440,000 year span, which he asserted was due to CO₂ driving temperature changes. But temperature changes can also affect atmospheric CO₂ levels. Davidson et al. (2015) examined the series and found that temperature Granger causes CO₂ but not the reverse. In other words on the time scales represented in the Vostok data the coherence in the series is primarily due to the influence of temperature on CO₂ levels not the feedback going from CO₂ to temperature.

In summary, the main statistical methods for attributing causation in climate data are optimal fingerprinting and time series analysis. Applications of the Allen and Tett (1999) optimal fingerprinting method dominate the attribution literature and have underpinned past IPCC conclusions, but results depend on the accuracy of climate models and the method has recently been criticized as inherently biased. Time series methods do not depend on climate models but require assumptions of their own and have generated results that have thus far not converged on a consensus.

7.4 Extreme event attribution (EEA)

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most regions in the mid-latitudes, medium confidence elsewhere
- Medium confidence in a decrease in extreme cold events in Australia, Africa and most of northern South America where observations allow trend estimation
- No evidence of emergence in the historical period of a change in river floods, heavy precipitation, drought, fire weather, severe wind storms, and tropical cyclones

While the overall issue of detecting changes in extreme weather events and their attribution remains ambiguous, most of the activity in this area relates to the attribution of single extreme weather events. The most prominent effort is the World Weather Attribution (WWA; worldweatherattribution.org), which is an international research initiative that focuses on extreme event attribution analyzing how climate change influences the likelihood and intensity of extreme weather events. The approach used by the WWA runs large ensembles of regional climate models to compare the event in today's climate, versus a pre-industrial counterfactual climate without human-caused warming.

WWA plays a prominent role in linking extreme weather to climate change and its press releases attract considerable public and policy discussions. However, the WWA's tendency to promote non-peer-reviewed findings, funding ties, open admission that they shape their analyses to serve purposes of litigation and other methodological challenges have sparked controversies, with critics questioning the robustness and impartiality of its conclusions (Pielke Jr. 2024). Despite these issues, WWA's work continues to shape climate science and media narratives. Technical criticisms of the approach include: neglect of a formal detection process; an implicit assumption that 100% of the post-industrial warming is caused by CO₂; and failure to adequately account for natural internal climate variability.

Because EEA is relatively new many basic methodological issues have yet to be settled in the expert literature. An important challenge is the lack of data. Extreme events are by definition rare. Many analyses of extreme event types (including the US National Assessment Reports) only evaluate data since 1950 or 1970. However, as emphasized by Chapter 8, many of the worst extreme weather and climate events in U.S. history occurred prior to the first half of the 20th century including in the early 19th century. And if paleoclimate reconstructions are considered, it becomes very difficult for an event to pass the detection thresholds of exceeding what is expected from natural variability, particularly if a reasonably sized geographic region is considered.

Another challenge is defining the event under study. There is a longstanding literature in statistics and econometrics on the challenge of analyzing data with outliers. The issue arises because a data series establishes a probability distribution defining the expected range of observations. If an outlier is observed it might indicate that the underlying process giving rise to the data distribution has changed (which in the weather context would mean a climatic change has been detected) or that the underlying process has multiple regimes each with a different probability distribution, in which case observing an outlier simply means we were temporarily in a different regime, but the system itself was unchanged. If a time series contains only a single outlier event at the end of the series it is not possible to determine which model is the correct one (Chen and Liu 1993). For instance, there might be an "ordinary" weather regime that yields a distribution of summer daytime highs in a particular coastal region, and a second "heatwave" regime that kicks in when an inland blocking event occurs, which yields a temperature distribution centered 15°C higher than the first one. A day with temperatures 13°C above normal would either be an extreme heat anomaly under the first regime or a somewhat cool event under the second, and we have no way in this case of knowing on statistical grounds which view is correct.

Visser and Petersen (2012) and Sardeshmukh et al. (2015) both point out that different distributions may fit observed data equally well but yield very different implications about the likelihood of a

specific weather event. Visser and Petersen argue that, in view of the deep uncertainties of extreme weather analysis drawing a connection between individual events and global climate change should be avoided. Furthermore the existence of an outlier at the end of a data series poses the problem that estimates of the event probabilities will be biased whether the outlier is included or excluded (Barlow et al. 2020). Methods to eliminate the bias have not yet been established, leading some experts (e.g. Miralles and Davison 2023) to argue that in settings in which a data series contains a single extreme event at the end, estimation of a return period for the extreme event will be so biased and uncertain it should be avoided altogether.

In spite of these concerns, the U.S. is presently considering something like the WWA, which is being investigated by a NASEM Panel on Attribution of Extreme Weather and Climate Events and their impacts (NASEM, 2025).

A case studies from a recent high impact extreme events in the U.S. is provided to illustrate the challenges and ambiguities in attributing the frequency and intensity of extreme weather events to human-caused warming.

7.4.1 Case study – 2021 Western North America heat wave

The 2021 Western North America heat wave was an extreme heat wave that affected much of Western North America in late June 2021. In particular, surface temperature records were set in Portland, OR (116°F; previous record 107°F) and Seattle, WA (108 °F; previous record 103°F) (Mass et al., 2024).

The WWA team garnered international headlines for their analysis and provided the following attribution statements (WWA, 2021; Philip et al., 2022):

- Based on observations and modeling, the occurrence of this heatwave was virtually impossible without human-caused climate change.
- The event is estimated to be about a 1 in 1000-year event in today's climate.
- The event would have been at least 150 times rarer without human-induced climate change.
- This heatwave was about 2°C hotter than it would have been if it had occurred at the beginning of the industrial revolution (when global mean temperatures were 1.2°C cooler than today).

But an important caveat to the first claim is that other researchers concluded, based on historical weather data, that while a heat wave of the magnitude observed was indeed virtually impossible without anthropogenic climate change, it was also virtually impossible *with* climate change. Bercos-Hickey (2022) noted “these temperatures were virtually impossible under any previously experienced meteorological conditions, with or without global warming.” McKinnon and Simpson (2022) stated “the most likely explanation remains that the weather event itself was ‘bad luck.’” The 2023 Oregon Climate Assessment (Fleischman 2023) concluded that the heat dome would have formed even without climate change and “There is no evidence that the highly unusual combination of weather features that drove the heat dome were made more likely by climate change, and climate models do not project an increase in the frequency of high-pressure ridges over the Pacific Northwest” (Fleischman 2023 p. 49).

Mass et al. (2024) summarizes the proximate sequence of compound events leading to the heat wave. There was a record-breaking midtropospheric ridge over the Pacific Northwest, forced by a tropical disturbance in the western Pacific. This produced record-breaking midtropospheric temperatures, strong subsidence in the lower atmosphere, low-level easterly flow that produced downslope warming on regional terrain and the removal of cooler marine air, and an approaching low-level trough that enhanced downslope flow. The event occurred at a time of maximum solar insolation, and drier-than-normal soil moisture. Using a storyline approach, Mass et al. assessed that there is no trend in drought and dry soils in the Pacific Northwest; there is no evidence of global warming producing stronger ridges of high pressure, and no observed trend in heat waves or record temperatures in the region. They concluded that although anthropogenic warming may have contributed as much as 2°F to the magnitude of the event, there is little evidence of further amplification of the event from increasing greenhouse gases.

A statistical analysis of a model-based attribution study of this heat wave was conducted by Bercos-Hickey et al. (2022). Because this event is a far outlier and far above the bounds of Generalized Extreme Value distributions fitted from historical data, they concluded that estimates of return times, quantitative changes in event magnitude and frequency, and probability of the extreme temperatures such as provided by the WWA are not accurate and should be interpreted as having low confidence. They found that hindcast attribution methods using an ensemble of regional climate models, combined with Pearl (2009) causal inferences, can provide limited and conditional information about the magnitude of the human influence on this heatwave – they provided a more highly constrained estimate that human activities caused a ~1.4°C–1.8°F increase in the daily maximum temperatures.

Zeder et al. (2023) also concluded that the methods employed by Philip et al. (2022) tend to overstate the rarity of extreme heat waves, leading to a biased perception of the effect of climate change on the heatwave event: “The tendency to overestimate the return period of observed extreme heatwave events may fuel the impression that seemingly impossible heatwave extremes are currently clustering at an unprecedented rate.”

The 2021 Western North America heatwave was a rare and unprecedented compound weather event, that broke century-old temperature records by as much as 9°F. While the WWA team received worldwide publicity for their rapid attribution claims blaming anthropogenic climate change, subsequent peer-reviewed analysis showed that the rare event was not made more probable by global warming.

7.5 Summary

There is an ongoing scientific debate around attribution methods, particularly in attributing extreme weather events to climate change. The IPCC has long cautioned that methods to establish causality in climate science are inherently uncertain and ultimately depend on expert judgement.

There are two areas of substantive criticism of the IPCC assessment of the causes of the recent warming: inadequate assessment of natural climate variability, and inappropriate statistical methods.

Detection of extreme weather events is challenged by their rarity, requiring a long data set and a choice of region and spatial scale to evaluate their occurrence against the background of natural weather and climate variability.

The most robust attribution statements for an extreme event relate to an incremental change (e.g. a temperature change in degrees or percent change in rainfall). Statements related to return times, quantitative changes in event magnitude and frequency, and probability of the extremes are not accurate owing to an inadequate amount of data, and are made with low confidence. There is no evidence in a change of weather or climate regime patterns from increasing greenhouse gases that would amplify or dampen extreme weather events, beyond basic thermodynamic considerations.

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From: Steven Koonin [steven.koonin@gmail.com]
Sent: 5/15/2025 2:49:50 PM
To: 'Travis Fisher' [travis.scott.fisher@gmail.com]
CC: 'Ross McKittrick' [ross.mckittrick@gmail.com]; 'Judith Curry' [curry.judith@cfanclimate.com]; 'John Christy' [climateman60@gmail.com]; 'Roy W. Spencer' [roywspencer@hotmail.com]
Subject: RE: New folder: 01.Report Draft

Your comment is well-taken. Would need to slightly rewrite the (now second) paragraph. I'll try to do that in my markup of the 01.Report version.

SEK

From: Travis Fisher <travis.scott.fisher@gmail.com>
Sent: Wednesday, May 14, 2025 11:25 PM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Ross McKittrick <ross.mckittrick@gmail.com>; Judith Curry <curry.judith@cfanclimate.com>; John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>
Subject: Re: New folder: 01.Report Draft

I'm just now seeing this thread after opening Chapter 1 for review. From now on, I'll work from the clean versions.

My one comment on Ch1 is attached.

On Wed, May 14, 2025 at 7:18 PM Steven Koonin <steven.koonin@gmail.com> wrote:

That works. Thanks.

SEK

From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Wednesday, May 14, 2025 7:17 PM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Judith Curry <curry.judith@cfanclimate.com>; John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Subject: Re: New folder: 01.Report Draft

This should get you in

https://www.dropbox.com/scl/fo/wahx6lpwzu33m5vyri8x/ANTU1qAQJ-zXCFzP_gsJcOs?rlkey=llz3qj9v46e1t5f4ywwxq7p8c&dl=0

This is for the parent folder. Let me know if it doesn't work.

On Wed, May 14, 2025 at 6:41 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Can you please send a link to the new folder?

Thanks.
Steven E. Koonin

> On May 14, 2025, at 15:27, Ross McKittrick <ross.mckittrick@gmail.com> wrote:

>

>

> Following our meeting today I created a new folder containing clean copies (all past tracked changes accepted) of all chapters.

> There are some marginal queries and in-line comments remaining to be resolved, missing Figure captions in a couple of places etc. If you are able to supply the missing info go ahead and do so. We will soon need to sign off on final text versions so please read through them.

> I propose that these should be the versions we talk through next week.

>

> Question: should there be a single list of references at the very end or should each chapter have its own reference list? Initially I thought the former but now I lean towards the latter.

>

From: Travis Fisher <travis.scott.fisher@gmail.com>
Sent: Wednesday, May 14, 2025 11:25 PM
To: Steven Koonin
Cc: Ross McKittrick; Judith Curry; John Christy; Roy W. Spencer
Subject: Re: New folder: 01.Report Draft
Attachments: 1 CO2.v.CACs.May11[SEK] - TF comment.docx

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This should get you in

https://www.dropbox.com/scl/fo/wahx6lpwzu33m5vyrr8x/ANTU1qAQJ-zXCFzP_gsJcOs?rlkey=l1z3qj9v46e1t5f4ywwxq7p8c&dl=0

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> Question: should there be a single list of references at the very end or should each chapter have its own reference list? Initially I thought the former but now I lean towards the latter.

>

1 Carbon dioxide as pollutant

In 2007, the Supreme Court ruled that GHGs (CO₂ among them) were “pollutants” subject to regulation under that Clean Air Act. That framework defines six types of so-called Criteria Air Contaminants (EPA, undated): .

While the definition of “pollutant” is ultimately a legal one, there are important scientific distinctions between CO₂ and the Criteria Air Contaminants—particulate matter, ground-level ozone, Sulfur Dioxide, Nitrogen Dioxide, Lead and carbon monoxide (CO). The latter are subject to regulatory control because they cause local problems depending on concentrations that include nuisances (odor, visibility), damage to plants, and, at high enough exposure levels, toxicological effects in humans. In contrast, CO₂ is odorless, does not affect visibility and has no toxicological effects at ambient levels. It is a naturally-occurring part of the atmosphere and a key component of human and plant respiration. CO₂ is essential for plant photosynthesis and higher levels are generally considered beneficial for vegetation. In these aspects, it is similar to water.

Ambient outdoor air today contains about 420 parts per million (ppm) CO₂, increasing at about 2 ppm per year. The US Occupational Safety and Health Administration issues guidelines for indoor workplaces in which elevated CO₂ might be encountered, such as where dry ice is used. The Permissible Exposure Limit is 5,000 ppm over 8 hours (OSHA 2024). Allen *et al.* (2015) reported evidence of diminished performance on some cognitive tasks among workers in office cubicles when exposed to CO₂ levels above 1,000-1,500 ppm. These levels are far larger than any plausible ambient outdoor value through the end of the 22nd century.

The growing amount of CO₂ in the atmosphere directly influences the earth system by promoting plant growth (global greening), thereby enhancing agricultural yields, and also by neutralizing ocean alkalinity. But the primary concern about CO₂ is its role as a greenhouse gas (GHG), that alters the earth’s energy balance. How the climate will respond to that influence is a complex question that will occupy much of this report.

Massachusetts v. EPA (2006) <https://www.oyez.org/cases/2006/05-1120>

US Environmental Protection Agency (Undated) Criteria Air Pollutants. <https://www.epa.gov/criteria-air-pollutants> accessed April 29 2025.

US Occupational Health and Safety Administration (2024) “OSHA Occupational Chemical Database: Carbon Dioxide” <https://www.osha.gov/chemicaldata/183>

Allen, Joseph G, Piers MacNaughton, Usha Satish, Suresh Santanam, Jose Vallarino and John D.S. Spengler (2015) Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments. *Environmental Health Perspectives* 124(6) pp. 805-812 <https://doi.org/10.1289/ehp.1510037>

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Wednesday, May 14, 2025 7:19 PM
To: 'Ross McKitrick'
Cc: 'Judith Curry'; 'John Christy'; 'Roy W. Spencer'; 'Travis Fisher'
Subject: RE: New folder: 01.Report Draft

That works. Thanks.

SEK

From: Ross McKitrick <ross.mckitrick@gmail.com>
Sent: Wednesday, May 14, 2025 7:17 PM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Judith Curry <curry.judith@cfanclimate.com>; John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Subject: Re: New folder: 01.Report Draft

This should get you in

https://www.dropbox.com/scl/fo/wahx6lpwzu33m5vyrr8x/ANTU1qAQJ-zXCFzP_gSJcOs?rlkey=l1z3qj9v46e1t5f4ywwxq7p8c&dl=0

This is for the parent folder. Let me know if it doesn't work.

On Wed, May 14, 2025 at 6:41 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Can you please send a link to the new folder?

Thanks.

Steven E. Koonin

> On May 14, 2025, at 15:27, Ross McKitrick <ross.mckitrick@gmail.com> wrote:

>

>

> Following our meeting today I created a new folder containing clean copies (all past tracked changes accepted) of all chapters.

> There are some marginal queries and in-line comments remaining to be resolved, missing Figure captions in a couple of places etc. If you are able to supply the missing info go ahead and do so. We will soon need to sign off on final text versions so please read through them.

> I propose that these should be the versions we talk through next week.

>

> Question: should there be a single list of references at the very end or should each chapter have its own reference list? Initially I thought the former but now I lean towards the latter.

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Sent: Wednesday, May 14, 2025 7:17 PM
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Cc: Judith Curry; John Christy; Roy W. Spencer; Travis Fisher
Subject: Re: New folder: 01.Report Draft

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https://www.dropbox.com/scl/fo/wahx6lpwzu33m5vyrr8x/ANTU1qAQJ-zXCFzP_gsJcOs?rlkey=11z3qj9v46e1t5f4ywwxq7p8c&dl=0

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From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Wednesday, May 14, 2025 6:28 PM
To: Judith Curry; John Christy; Roy W. Spencer; Steven Koonin; Travis Fisher
Subject: New folder: 01.Report Draft

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I propose that these should be the versions we talk through next week.

Question: should there be a single list of references at the very end or should each chapter have its own reference list? Initially I thought the former but now I lean towards the latter.

From: Judith Curry <curry.judith@gmail.com>
Sent: Sunday, May 11, 2025 6:20 PM
To: Roy Spencer
Cc: Travis Fisher; Ross McKittrick; Steven Koonin; John Christy
Subject: Re: Ch 8 Extreme weather

Roy is correct. There is a total dearth of analysis on this topic, i am working with insurance companies to try to address this issue. But the summary statement from the AR6 saying "no signal" supports us not doing very much with this issue in this report (other than to mention the media hype against no evidence). Tornadoes are the only topic where there is any kind of analysis to draw from.

On Sun, May 11, 2025 at 12:59 PM Roy Spencer <roywspencer@hotmail.com> wrote:

Regarding tornadoes, strong to intense tornadoes in the US are down 50%, probably due to fewer Canadian cold air outbreaks over the western US in spring. Not sure whether anyone has added that yet. Severe thunderstorms require wind shear which is a function of cold and warm air masses, which is a mid-latitude issue. Instead, physicists and maths folks think it's thermodynamic buoyant energy that's important but if that was true the tropics would be full of severe thunderstorms.

-Roy

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: Travis Fisher <travis.scott.fisher@gmail.com>
Date: 5/11/25 12:23 PM (GMT-06:00)
To: Judith Curry <curry.judith@gmail.com>
Cc: Ross McKittrick <ross.mckittrick@gmail.com>, Steven Koonin <steven.koonin@gmail.com>, John Christy <climateman60@gmail.com>, "Roy W. Spencer" <roywspencer@hotmail.com>
Subject: Re: Ch 8 Extreme weather

Will do. Apologies for the rambling email... I was trying to write with a kid on my lap. Just know I'm here to help!

On Sun, May 11, 2025 at 11:53 AM Judith Curry <curry.judith@gmail.com> wrote:

Travis, your comments on readability, gaps and red flag statements would be VERY helpful. The chapters all have a complete draft, but some are still in flux

On Sun, May 11, 2025 at 8:15 AM Travis Fisher <travis.scott.fisher@gmail.com> wrote:

As the non-expert member of the team, one of my contributions could be to provide input from the point of view of a reader who doesn't live and breathe these materials on a daily basis. With that in mind, I have a few observations that might help:

1) That said, I see no problem with adding more material. If the team is torn between the short version and the long version of any chapter, my preference is to leave more material and leave it to the reader whether to

dig in or skim. We don't exactly have a word or page limit on this. Also, the point about cherry-picking starting points for the data is very compelling to me. It reminds me of the first time I saw the chart of air pollution data with reference to EPA's formation. Of course the trend is sharply down for criteria pollutants after 1970, but it was on a similar trend *before* 1970 as well. Those types of data-based expositions can be very powerful in refuting common misunderstandings.

2) Some of the issues you all know incredibly well could use more elaboration for the uninitiated reader, especially when you agree fully with the consensus, IPCC, or NCA view. As one example, I was looking for more info on convective events in the extreme weather chapter. I know they are covered briefly, but my reaction as the non-expert was surprise at how little focus the consensus view gives them (and how lightly that fact was discussed in your chapter). I think we should emphasize the areas where, at least according to a typical reading of the news and popular narratives, climate change is blamed for things that aren't even on an upward trend. Thunderstorms and hailstorms are certainly part of that narrative. I'm less familiar with tornadoes entering the narrative, but it was news to me that there is essentially zero correlation with temperatures, and that type of information could be news to the typical reader as well. In other words, you could emphasize the areas where you all agree with IPCC/NCA/etc, which in turn would help anchor this report to the consensus view. That borders on a political or public affairs consideration, I know, so please feel free to ignore it completely.

3) I can see why the Secretary chose this team. You all are world-class experts. It's been a privilege to watch this report come together, and I'll do everything in my power to make it something you all can be proud of. If you want me to add comment bubbles to flag areas where the non-expert might trip up, I'd be happy to do that. Or if there's anything else I can do aside from the next glossary and the cover letter from the Secretary (and coordination with EPA), please let me know.

4) I took too long to hit send on this email, and I see a new one from Judy. +1 to Judy's point about leaving evaluations and judgments out of the body of the report. I may also try to flag areas where I see opinions or the inevitable pejorative. Personally, I had no idea how slick some of the NCA findings were in terms of narrowly defining the state of the climate to generate the appearance of a crisis, and I have become a new level of cynical after seeing it more clearly, thanks to you all. I'm excited to see the much-needed conversations this report will generate.

Best,
Travis

On Sun, May 11, 2025 at 11:06 AM Judith Curry <curry.judith@gmail.com> wrote:

Well the point of JC and RS analyses later in the chapter demonstrate the importance of looking back prior to 1950. And i think we should stick to conclusion statements in the SPM and Chapter summaries, rather than the text of the report that cites primary references (that looks like cherry picking). And AR6 is the main doc driving policy arguments; i don't think EPA lawyers are going to go back to AR5

On Sun, May 11, 2025 at 7:38 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

My concerns are that these excerpts leave out too much valuable material and that they lead with the AR6 cherry-picked 1950s as the starting point for trends. Both with respect to heatwaves and precip the only way to detect increases is to compare back to the 50s. If they include the 1930s or further back the heatwave picture falls apart, and as we show further in the chapter the precip picture falls apart either starting in the 70s or the 1800s. This selection puts us in a weak position where we will appear to be arguing against IPCC assessments using our own data, even though the more complete survey shows that our data aligns with what the assessments have been saying all along.

One reason to include material from the past assessment reports is that people have been hearing a narrative about extreme weather for 20+ years. A brief survey won't suffice to overcome the cognitive dissonance we're up against in this chapter. The comprehensive survey of IPCC and NCA material is the only way to overcome it. If we only show the AR6 they might think that's somehow new whereas prior reports said something else. I want to show convincingly that the message today is about the same as it's always been.

For those of us who know what the IPCC says and has said in the past it might seem tedious to quote it at such length. But I've presented to enough undergrad classes and public audiences to know that people don't find these quotes boring, they find them incredible. If it's a question of chapter order I don't mind if there's a brief preface then the whole collection goes into the chapter appendix, but I see no benefit to omitting the material and considerable gain from including it. And I still think the best option is to lead with it.

What say others?

On Sat, May 10, 2025 at 5:55 PM Judith Curry <curry.judith@gmail.com> wrote:

See attached for my smash down of section 8.2 (13 down to 2 pages). I included on detection statements (no attribution or projections); focused on AR6 and included some statements from NCA17 and SREX that provided additional detail. I focused on summary statements from the SPM and chapter summaries (without citations of individual papers)

Let me know what you think, and whether you prefer it up front or at the end (maybe an appendix)

On Sat, May 10, 2025 at 11:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:

I like John's suggestion.

Steven E. Koonin

On May 10, 2025, at 14:36, John Christy <climateman60@gmail.com> wrote:

Judy

Would this work. Put the IPCC/NCA quotes in bold up front with a little introductory remark then add "full statements in context in appendix"?

John C.

Sent from my iPhone

On May 10, 2025, at 5:49 AM, Judith Curry <curry.judith@gmail.com> wrote:

I'm working on CH 8 Extreme Weather front end today, more soon

On Sat, May 10, 2025 at 8:37 AM Steven Koonin

<steven.koonin@gmail.com> wrote:

Yes! In the exec summary and the chapter preface we must repeat something like “Contrary to popular perception...”

Steven E. Koonin

On May 10, 2025, at 11:19, Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

This just appeared in the Daily Mail

<https://www.dailymail.co.uk/sciencetech/article-14686539/climate-change-affect-YOU-heatwaves-floods.html>

The extreme weather alarmism angle has been non-stop for years. People are saturated with the message that climate change = extreme weather and all scientists say it's bad and getting worse due to GHGs. It will take a lot of hammering on the theme to convince people how much they've been misled. So I don't mind if the first 15 pages of this chapter consists of mind-numbing repetition of the message that scientists don't say this and have never said it. At this point I want to hold the readers' faces in it until their limbs stop twitching and then they'll be receptive to the rest of the material.

On Fri, May 9, 2025 at 3:09 PM Judith Curry

<curry.judith@gmail.com> wrote:

I agree we should have something up front, but not pages. Will propose something more specific

On Fri, May 9, 2025 at 12:06 PM Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

My read of the discussion on May 8 was that Steve made a strong pitch to move the survey back up front and you and Roy concurred. I'll let you guys debate it.

On Fri, May 9, 2025 at 3:01 PM Judith Curry

<curry.judith@gmail.com> wrote:

actually no, i thought we left this as an appendix or something (i don't think it is necessary tho). We need some sort of a summary on what the IPCC found

I have this para in the attribution chapter

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table 12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most regions in the mid-latitudes, medium confidence elsewhere
- Medium confidence in a decrease in extreme cold events in Australia, Africa and most of northern South America where observations allow trend estimation
- No evidence of emergence in the historical period of a change in river floods, heavy precipitation, drought, fire weather, severe wind storms, and tropical cyclones

On Fri, May 9, 2025 at 11:55 AM Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

I thought you said (May 8) you liked the suggestion to move them all back to the front.

On Fri, May 9, 2025 at 2:52 PM Judith Curry

<curry.judith@gmail.com> wrote:

I don't like having pages of IPCC/NCA citations (IMO the key issue is a lot of uncertainty and

disagreement, and the inconsistency between chapters 11 and 12 of AR6). If we do include a shortened version of this, i would focus only on AR6, either global or US region.

On Fri, May 9, 2025 at 11:45 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

In the attached Extreme Weather chapter draft I moved the IPCC/NCA excerpts back into the main body per the discussion here and renumbered all the sections and figures mutatis mutandis.

The AI summary is not bad but does need some work. Admittedly it's a lot of stuff to summarize, although the recurring theme is that trends aren't detectable and attribution to GHGs is currently not possible, in general.

On Thu, May 8, 2025 at 1:45 PM Roy Spencer <roywspencer@hotmail.com> wrote:

This way forward is fine with me.

-Roy

From: Judith Curry <curry.judith@gmail.com>

Sent: Thursday, May 8, 2025 12:43 PM

To: John Christy <climateman60@gmail.com>

Cc: Steven Koonin <steven.koonin@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>

Subject: Re: Ch 8 Extreme weather

I think starting with IPCC up front is very useful to provide a reference point, and discussing problems with NCA motivates the unpublished data analysis

On Thu, May 8, 2025 at 10:36 AM John Christy <climateman60@gmail.com> wrote:

Ultimately the order will likely not matter. We are somewhat conflicted. On one hand we show the Assessments are consistent with our conclusions about extreme weather, but on the other hand we find them (especially NCAs) deceptive in presenting the information that skews their results to lean toward alarmism. This is true of other chapters as well.

At the least we should mention this nuance perhaps up front.

John C.

Sent from my iPhone

On May 8, 2025, at 6:23 AM, Judith Curry <curry.judith@gmail.com> wrote:

I also agree with this organization, was thinking the same thing

On Thu, May 8, 2025 at 8:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:

Attached are my comments/edits on Chapter 8.

I'd like to make a strong pitch to reorder the text so that the survey of previous assessments comes first, then followed by the new work from John and Ross. There are several reasons for this that I can elaborate, but the most important is that the official assessments already make the case and, no offense guys, carry far more authority in the non-expert world.

SEK

PS Note for interest and amusement the AI-generated summary section.

From: Ross McKittrick
<ross.mckittrick@gmail.com>
Sent: Tuesday, May 6, 2025 1:05 PM
To: John Christy
<climateman60@gmail.com>
Cc: Judith Curry
<curry.judith@gmail.com>; Roy W. Spencer

<roywspencer@hotmail.com>; Travis
Fisher
<travis.scott.fisher@gmail.com>;
Steven Koonin
<steven.koonin@googlemail.com>
Subject: Re: Ch 8 Extreme weather

Here's another edition of Ch 8 on extremes taking Judy's and John's points into account. The IPCC/NCA review is ported to an Appendix. I added a paragraph about LTP to the intro. I've incorporated the NE data. The bulk of the chapter is John's US temperature and precip data analysis with some additional material on wildfires, drought and TCs. For the US temperature extremes I moved the range figure to come just after the hot/cold extremes count because I think they both make a coherent point namely that the US becoming less extreme because heat events are rising more slowly than cold events are warming. There will still need to be an overall chapter summary but I'm going to move on to other chapters now. I'll put this in the Dropbox.

On Tue, May 6, 2025 at 12:12 PM
John Christy
<climateman60@gmail.com>
wrote:

All

We can fill in without much trouble the change, or lack thereof, of “high impact” weather events (mainly wind and flooding

like hurricanes, tornadoes etc) in the CONUS Extreme chapter. The temp and precip metrics are important because they are just long enough to essentially tell us Mother Nature has a mind of her own.

1. I'll look at Ross's version of 8 soon, but my hope was that Ross would translate the statistical remarks into the correct language(eg are their more precise words that chaotic, episodic, stochastic, etc).

2. We have analyses of the CONUS with more complete datasets than the NCA used (recall NCA analyses depended essentially on a small group at NCEI using datasets that (a) were not very consistent in time, (b) could promote alarm and (c) already easy for them to get to. Our datasets have literally hundreds of thousands of manually keyed-in observations for temporal consistency. In other words, this lets people know we can address these issues from soup to nuts - we're not armchair climate scientists ... we can reproduce what they did, but make the analysis more comprehensive to address the questions.

John C.

Sent from my iPhone

On May 6, 2025, at
4:14 AM, Ross
McKitrick

<ross.mckitrick@gmail.com> wrote:

Just read your attribution chapter. I hadn't picked up on the gap between IPCC Ch 11 vs Ch 12 language but i see your point that rather than promoting one set of attribution findings we should explain that even within the same AR different authors assessed things differently. One option is to leave Ch 6 where it is but reverse the order of Ch 7 and 8 while retitling the latter as you suggest. That way, having established the extreme weather types for which there are no detectable trends it will more naturally follow that they won't be discussed in the attribution chapter.

On Tue, May 6,
2025 at 9:45 AM
Judith Curry
<curry.judith@gmail.com>
curry.judith@gmail.com> wrote:

Ok, but the
summary table
(12.12 from AR6)
is inconsistent
with conclusions
in AR6 ch 11 (I
point this out in
section 6.4 of my
attribution
chapter).

In my mind, the
main point is
disagreement and
ambiguity I
would suggest
chapter 8 going
before chapter 6,
retitling it as US
Weather and
Climate
Extremes, and
make it more of a
data chapter, not
an attribution
chapter (I would
put table 12.12 in
the attribution
chapter if you
want to include
the actual table)

On Tue, May 6,
2025 at 6:39 AM
Ross McKittrick
<ross.mckittrick@gmail.com>
ross.mckittrick@gmail.com>
wrote:

I like john's material too which is why I included it and am working on the extended regional analyses. But on this topic people are heavily primed to believe that extreme weather of all kinds is getting worse due to climate change. The assertion shows up everywhere climate change is discussed including in academic papers. I think it is very valuable to show people that neither the IPCC nor the NCA support such this view. We should at least lead off with the summary table. The library of quotes can go to an appendix but I have found in my public speaking that they have considerable persuasive force for most people. We also need to address floods, droughts, hurricane landfalls, tornadoes etc. I don't see any

reason to delete
all that material.

On Tue, May 6,
2025 at 9:22 AM
Judith Curry
<curry.judith@gmail.com>
wrote:

I actually liked
John's
chapter. I
would have
retitled it "US
temperature and
rainfall
extremes"

I think this is
more relevant
than a complete
rehash of
everything the
last 3 IPCC
reports have
stated for every
conceivable
severe weather
event.

John's version
meshes very
well with my
version of
chapter 6. Read
especially
section 6.4 of
my chapter. I
note a
discrepancy
between
chapters 11 and
12 in terms of
detecting and
attributing
extreme

events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the problems/challenges, and topics that are particularly relevant for the US

On Mon, May 5, 2025 at 7:47 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I have wrangled the extreme weather chapter into something I hope flows better and is more readable. I adopted Judy's editorial changes and then the new changes I made are in red. I added some new Figures showing results on PC and SE data and will add the

NE chart when
I get the data. I
also made
some labeling
suggestions
including for
the 3 rainfall
charts that are
hard to
understand.
Section
summaries and
an overall
summary are
still needed.

Ross

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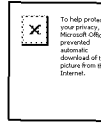
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Judith Curry, President
CFAN - Climate Forecast Applications Netw
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803
<http://www.cfanclimate.net>

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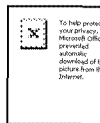
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<http://www.cfanclimate.net>



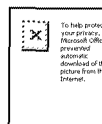
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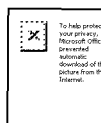
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curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>

From: Judith Curry [curry.judith@gmail.com]
Sent: 5/11/2025 10:15:28 PM
To: Ross McKittrick [ross.mckittrick@gmail.com]
CC: Roy Spencer [roywspencer@hotmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]; Steven Koonin [steven.koonin@gmail.com]; John Christy [climateman60@gmail.com]
Subject: Re: Ch 8 Extreme weather

Well this is the whole point; IPCC is making alarming statements (lets summarize them simply), and then we provide longer term data that refutes their conclusions.

On Sun, May 11, 2025 at 1:59 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

No I was responding to Judy's proposed re-do of the intro section with a much reduced set of IPCC quotes. The first few selections report trends since the 1950s which for both heatwaves and precip create a different and more alarmist impression than ones based on starting in the 1930s (or, in the case of the US, starting either earlier or later).

On Sun, May 11, 2025 at 4:49 PM Roy Spencer <roywspencer@hotmail.com> wrote:

Not sure whether the 1950s start comment was related to my tornadoes comment... US tornado stats didn't start until the 1950s. I was responding to Travis' query about severe convective storms.

-Roy

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: Ross McKittrick <ross.mckittrick@gmail.com>
Date: 5/11/25 3:27 PM (GMT-06:00)
To: Roy Spencer <roywspencer@hotmail.com>
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Subject: Re: Ch 8 Extreme weather

I originally assembled the set of quotations for counsel in a Canadian court case pre-AR6, then showed it to lawyers in a different court case and too they thought it was very useful, and asked me to add AR6 material to it. So I wouldn't make a decision based on what we think lawyers might need or want.

The fact that later in the chapter we demonstrate the importance of looking pre-1950 confirms the point that we shouldn't lead with IPCC Summary statements based on post-1950 trends. And we're not limited to using SPM statements especially ones we plan to rebut.

On Sun, May 11, 2025 at 3:59 PM Roy Spencer <roywspencer@hotmail.com> wrote:

Regarding tornadoes, strong to intense tornadoes in the US are down 50%, probably due to fewer Canadian cold air outbreaks over the western US in spring. Not sure whether anyone has added that yet. Severe thunderstorms require wind shear which is a function of cold and warm air masses, which is a mid-latitude issue. Instead, physicists and maths folks think it's thermodynamic buoyant energy that's important but if that was true the tropics would be full of severe thunderstorms.

-Roy

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: Travis Fisher <travis.scott.fisher@gmail.com>

Date: 5/11/25 12:23 PM (GMT-06:00)

To: Judith Curry <curry.judith@gmail.com>

Cc: Ross McKittrick <ross.mckittrick@gmail.com>, Steven Koonin <steven.koonin@gmail.com>, John Christy <climateman60@gmail.com>, "Roy W. Spencer" <roywspencer@hotmail.com>

Subject: Re: Ch 8 Extreme weather

Will do. Apologies for the rambling email... I was trying to write with a kid on my lap. Just know I'm here to help!

On Sun, May 11, 2025 at 11:53 AM Judith Curry <curry.judith@gmail.com> wrote:

Travis, your comments on readability, gaps and red flag statements would be VERY helpful. The chapters all have a complete draft, but some are still in flux

On Sun, May 11, 2025 at 8:15 AM Travis Fisher <travis.scott.fisher@gmail.com> wrote:

As the non-expert member of the team, one of my contributions could be to provide input from the point of view of a reader who doesn't live and breathe these materials on a daily basis. With that in mind, I have a few observations that might help:

1) That said, I see no problem with adding more material. If the team is torn between the short version and the long version of any chapter, my preference is to leave more material and leave it to the reader whether to dig in or skim. We don't exactly have a word or page limit on this. Also, the point about cherry-picking starting points for the data is very compelling to me. It reminds me of the first time I saw the chart of air pollution data with reference to EPA's formation. Of course the trend is sharply down for criteria pollutants after 1970, but it was on a similar trend *before* 1970 as well. Those types of data-based expositions can be very powerful in refuting common misunderstandings.

2) Some of the issues you all know incredibly well could use more elaboration for the uninitiated reader, especially when you agree fully with the consensus, IPCC, or NCA view. As one example, I was looking for more info on convective events in the extreme weather chapter. I know they are covered briefly, but my reaction as the non-expert was surprise at how little focus the consensus view gives them (and how lightly that fact was discussed in your chapter). I think we should emphasize the areas where, at least according to a typical reading of the news and popular narratives, climate change is blamed for things that aren't even on an upward trend. Thunderstorms and hailstorms are certainly part of that narrative. I'm less familiar with tornadoes entering the narrative, but it was news to me that there is essentially zero correlation with temperatures, and that type of information could be news to the typical reader as well. In other words, you could emphasize the areas where you all agree with IPCC/NCA/etc, which in turn would help anchor this report to the consensus view. That borders on a political or public affairs consideration, I know, so please feel free to ignore it completely.

3) I can see why the Secretary chose this team. You all are world-class experts. It's been a privilege to watch this report come together, and I'll do everything in my power to make it something you all can be proud of. If you want me to add comment bubbles to flag areas where the non-expert might trip up, I'd be

happy to do that. Or if there's anything else I can do aside from the next glossary and the cover letter from the Secretary (and coordination with EPA), please let me know.

4) I took too long to hit send on this email, and I see a new one from Judy. +1 to Judy's point about leaving evaluations and judgments out of the body of the report. I may also try to flag areas where I see opinions or the inevitable pejorative. Personally, I had no idea how slick some of the NCA findings were in terms of narrowly defining the state of the climate to generate the appearance of a crisis, and I have become a new level of cynical after seeing it more clearly, thanks to you all. I'm excited to see the much-needed conversations this report will generate.

Best,
Travis

On Sun, May 11, 2025 at 11:06 AM Judith Curry <curry.judith@gmail.com> wrote:

Well the point of JC and RS analyses later in the chapter demonstrate the importance of looking back prior to 1950. And i think we should stick to conclusion statements in the SPM and Chapter summaries, rather than the text of the report that cites primary references (that looks like cherry picking). And AR6 is the main doc driving policy arguments; i don't think EPA lawyers are going to go back to AR5

On Sun, May 11, 2025 at 7:38 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

My concerns are that these excerpts leave out too much valuable material and that they lead with the AR6 cherry-picked 1950s as the starting point for trends. Both with respect to heatwaves and precip the only way to detect increases is to compare back to the 50s. If they include the 1930s or further back the heatwave picture falls apart, and as we show further in the chapter the precip picture falls apart either starting in the 70s or the 1800s. This selection puts us in a weak position where we will appear to be arguing against IPCC assessments using our own data, even though the more complete survey shows that our data aligns with what the assessments have been saying all along.

One reason to include material from the past assessment reports is that people have been hearing a narrative about extreme weather for 20+ years. A brief survey won't suffice to overcome the cognitive dissonance we're up against in this chapter. The comprehensive survey of IPCC and NCA material is the only way to overcome it. If we only show the AR6 they might think that's somehow new whereas prior reports said something else. I want to show convincingly that the message today is about the same as it's always been.

For those of us who know what the IPCC says and has said in the past it might seem tedious to quote it at such length. But I've presented to enough undergrad classes and public audiences to know that people don't find these quotes boring, they find them incredible. If it's a question of chapter order I don't mind if there's a brief preface then the whole collection goes into the chapter appendix, but I see no benefit to omitting the material and considerable gain from including it. And I still think the best option is to lead with it.

What say others?

On Sat, May 10, 2025 at 5:55 PM Judith Curry <curry.judith@gmail.com> wrote:

See attached for my smash down of section 8.2 (13 down to 2 pages). I included on detection statements (no attribution or projections); focused on AR6 and included some statements from NCA17 and SREX that provided additional detail. I focused on summary statements from the SPM and chapter summaries (without citations of individual papers)

Let me know what you think, and whether you prefer it up front or at the end (maybe an appendix)

On Sat, May 10, 2025 at 11:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:
I like John's suggestion.

Steven E. Koonin

On May 10, 2025, at 14:36, John Christy <climateman60@gmail.com> wrote:

Judy

Would this work. Put the IPCC/NCA quotes in bold up front with a little introductory remark then add "full statements in context in appendix"?

John C.

Sent from my iPhone

On May 10, 2025, at 5:49 AM, Judith Curry <curry.judith@gmail.com> wrote:

I'm working on CH 8 Extreme Weather front end today, more soon

On Sat, May 10, 2025 at 8:37 AM Steven Koonin <steven.koonin@gmail.com> wrote:
Yes! In the exec summary and the chapter preface we must repeat something like "Contrary to popular perception..."

Steven E. Koonin

On May 10, 2025, at 11:19, Ross McKittrick <ross.mckittrick@gmail.com> wrote:

This just appeared in the Daily Mail
<https://www.dailymail.co.uk/sciencetech/article-14686539/climate-change-affect-YOU-heatwaves-floods.html>

The extreme weather alarmism angle has been non-stop for years. People are saturated with the message that climate change = extreme weather and all scientists say it's bad and getting worse due to GHGs. It will take a lot of hammering on the theme to convince people how much they've been misled. So I don't mind if the first 15 pages of this chapter consists of mind-numbing repetition of the message that scientists don't say this and have never said it. At this point I want to hold the readers' faces in it until their limbs stop twitching and then they'll be receptive to the rest of the material.

On Fri, May 9, 2025 at 3:09 PM Judith Curry <curry.judith@gmail.com> wrote:

I agree we should have something up front, but not pages. Will propose something more specific

On Fri, May 9, 2025 at 12:06 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

My read of the discussion on May 8 was that Steve made a strong pitch to move the survey back up front and you and Roy concurred. I'll let you guys debate it.

On Fri, May 9, 2025 at 3:01 PM Judith Curry <curry.judith@gmail.com> wrote:

actually no, i thought we left this as an appendix or something (i don't think it is necessary tho). We need some sort of a summary on what the IPCC found

I have this para in the attribution chapter

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table 12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most regions in the mid-latitudes, medium confidence elsewhere
- Medium confidence in a decrease in extreme cold events in Australia, Africa and most of northern South America where observations allow trend estimation
- No evidence of emergence in the historical period of a change in river floods, heavy precipitation, drought, fire weather, severe wind storms, and tropical cyclones

On Fri, May 9, 2025 at 11:55 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I thought you said (May 8) you liked the suggestion to move them all back to the front.

On Fri, May 9, 2025 at 2:52 PM Judith Curry <curry.judith@gmail.com> wrote:

I don't like having pages of IPCC/NCA citations (IMO the key issue is a lot of uncertainty and disagreement, and the inconsistency between chapters 11 and 12 of AR6). If we do include a shortened version of this, i would focus only on AR6, either global or US region.

On Fri, May 9, 2025 at 11:45 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

In the attached Extreme Weather chapter draft I moved the IPCC/NCA excerpts back into the main body per the discussion here and renumbered all the sections and figures mutatis mutandis.

The AI summary is not bad but does need some work. Admittedly it's a lot of stuff to summarize, although the recurring theme is that trends aren't detectable and attribution to GHGs is currently not possible, in general.

On Thu, May 8, 2025 at 1:45 PM Roy Spencer <roywspencer@hotmail.com> wrote:

This way forward is fine with me.

-Roy

From: Judith Curry <curry.judith@gmail.com>

Sent: Thursday, May 8, 2025 12:43 PM

To: John Christy <climateman60@gmail.com>

Cc: Steven Koonin <steven.koonin@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>

Subject: Re: Ch 8 Extreme weather

I think starting with IPCC up front is very useful to provide a reference point, and discussing problems with NCA motivates the unpublished data analysis

On Thu, May 8, 2025 at 10:36 AM John Christy <climateman60@gmail.com> wrote:

Ultimately the order will likely not matter. We are somewhat conflicted. On one hand we show the Assessments are consistent with our conclusions about extreme weather, but on the other hand we find them (especially NCAs) deceptive in presenting the information that skews their results to lean toward alarmism. This is true of other chapters as well.

At the least we should mention this nuance perhaps up front.

John C.

Sent from my iPhone

On May 8, 2025, at 6:23 AM, Judith Curry <curry.judith@gmail.com> wrote:

I also agree with this organization, was thinking the same thing

On Thu, May 8, 2025 at 8:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:

Attached are my comments/edits on Chapter 8.

I'd like to make a strong pitch to reorder the text so that the survey of previous assessments comes first, then followed by the new work from John and Ross. There are several reasons for this that I can elaborate, but the most important is that the official assessments already make the case and, no offense guys, carry far more authority in the non-expert world.

SEK

PS Note for interest and amusement the AI-generated summary section.

From: Ross McKittrick <ross.mckittrick@gmail.com>

Sent: Tuesday, May 6, 2025 1:05 PM

To: John Christy <climateman60@gmail.com>

Cc: Judith Curry <curry.judith@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>; Steven Koonin <steven.koonin@googlemail.com>

Subject: Re: Ch 8 Extreme weather

Here's another edition of Ch 8 on extremes taking Judy's and John's points into account. The IPCC/NCA review is ported to an Appendix. I added a paragraph about LTP to the intro. I've incorporated the NE data. The bulk of the chapter is John's US temperature and precip data analysis with some additional material on wildfires, drought and TCs. For the US temperature extremes I moved the range figure to come just after the hot/cold extremes count because I think they both make a coherent point namely that the US becoming less extreme because heat events are rising more slowly than cold events are warming. There will still need to be an overall chapter summary but I'm going to move on to other chapters now. I'll put this in the Dropbox.

On Tue, May 6, 2025 at 12:12 PM John Christy <climateman60@gmail.com> wrote:

All

We can fill in without much trouble the change, or lack thereof, of "high impact" weather events (mainly wind and flooding like hurricanes, tornadoes etc) in the CONUS Extreme chapter. The temp and precip metrics are important because they are just long enough to essentially tell us Mother Nature has a mind of her own.

1. I'll look at Ross's version of 8 soon, but my hope was that Ross would translate the statistical remarks into the correct language(eg are their more precise words that chaotic, episodic, stochastic, etc).

2. We have analyses of the CONUS with more complete datasets than the NCA used (recall NCA analyses depended essentially on a small group at NCEI using datasets that (a) were not very consistent in time, (b) could promote alarm and (c) already easy for them to get to. Our datasets have literally hundreds of thousands of manually keyed-in observations for temporal consistency. In other words, this lets people know we can address these issues from soup to nuts - we're not armchair climate scientists ... we can reproduce what they did, but make the analysis more comprehensive to address the questions.

John C.

Sent from my iPhone

On May 6, 2025, at 4:14 AM, Ross McKittrick

<ross.mckitrick@gmail.com> wrote:

Just read your attribution chapter. I hadn't picked up on the gap between IPCC Ch 11 vs Ch 12 language but i see your point that rather than promoting one set of attribution findings we should explain that even within the same AR different authors assessed things differently. One option is to leave Ch 6 where it is but reverse the order of Ch 7 and 8 while retitling the latter as you suggest. That way, having established the extreme weather types for which there are no detectable trends it will more naturally follow that they won't be discussed in the attribution chapter.

On Tue, May 6, 2025 at 9:45 AM Judith Curry <curry.judith@gmail.com> wrote:

Ok, but the summary table (12.12 from AR6) is inconsistent with conclusions in AR6 ch 11 (I point this out in section 6.4 of my attribution chapter).

In my mind, the main point is disagreement and ambiguity I would suggest chapter 8 going before chapter 6, retitling it as US Weather and Climate Extremes, and make it more of a data chapter, not an attribution chapter (I would put table 12.12 in the attribution chapter if you want to include the actual table)

On Tue, May 6, 2025 at 6:39 AM Ross McKitrick <ross.mckitrick@gmail.com> wrote:

I like john's material too which is why I included it and am working on the extended regional analyses. But on this topic people are heavily primed to believe that extreme weather of all kinds is getting worse due to climate change. The assertion shows up everywhere climate change is discussed including in academic papers. I think it is very valuable to show people that neither the IPCC nor the NCA support such this view. We should at least lead off with the summary table. The library of quotes can go to an appendix but I have found in my public speaking that they have considerable persuasive force for most people. We also need to address floods, droughts, hurricane landfalls, tornadoes etc. I don't see any reason to delete all that material.

On Tue, May 6, 2025 at 9:22 AM Judith Curry <curry.judith@gmail.com> wrote:

I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes"

I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable severe weather event.

John's version meshes very well with my version of chapter 6. Read especially section 6.4 of my chapter. I note a discrepancy between chapters 11 and 12 in terms of detecting and attributing extreme events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the problems/challenges, and topics that are particularly relevant for the US

On Mon, May 5, 2025 at 7:47 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I have wrangled the extreme weather chapter into something I hope flows better and is more readable. I adopted Judy's editorial changes and then the new changes I made are in red. I added some new Figures showing results on PC and SE data and will add the NE chart when I get the data. I also made some labeling suggestions including for the 3 rainfall charts that are hard to understand. Section summaries and an overall summary are still needed.

Ross

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<~WRD2740.jpg>

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Network
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+1.404.803.2012
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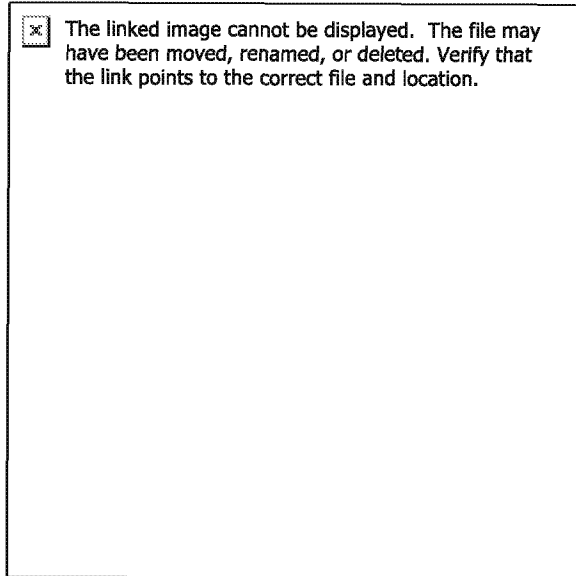
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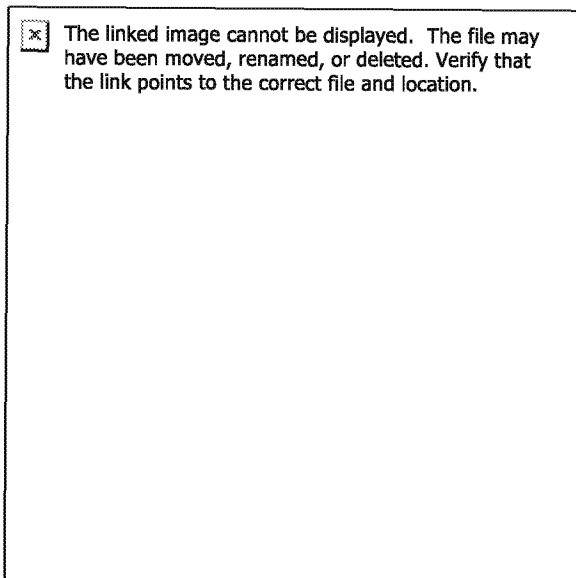
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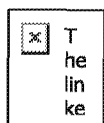
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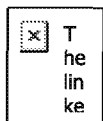
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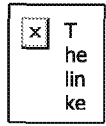


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From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Sunday, May 11, 2025 5:00 PM
To: Roy Spencer
Cc: Travis Fisher; Judith Curry; Steven Koonin; John Christy
Subject: Re: Ch 8 Extreme weather

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As the non-expert member of the team, one of my contributions could be to provide input from the point of view of a reader who doesn't live and breathe these materials on a daily basis. With that in mind, I have a few observations that might help:

1) That said, I see no problem with adding more material. If the team is torn between the short version and the long version of any chapter, my preference is to leave more material and leave it to the reader whether to dig in or skim. We don't exactly have a word or page limit on this. Also, the point about cherry-picking starting points for the data is very compelling to me. It reminds me of the first time I saw the chart of air pollution data with reference to EPA's formation. Of course the trend is sharply down for criteria pollutants after 1970, but it was on a similar trend *before* 1970 as well. Those types of data-based expositions can be very powerful in refuting common misunderstandings.

2) Some of the issues you all know incredibly well could use more elaboration for the uninitiated reader, especially when you agree fully with the consensus, IPCC, or NCA view. As one example, I was looking for more info on convective events in the extreme weather chapter. I know they are covered briefly, but my reaction as the non-expert was surprise at how little focus the consensus view gives them (and how lightly that fact was discussed in your chapter). I think we should emphasize the areas where, at least according to a typical reading of the news and popular narratives, climate change is blamed for things that aren't even on an upward trend. Thunderstorms and hailstorms are certainly part of that narrative. I'm less familiar with tornadoes entering the narrative, but it was news to me that there is essentially zero correlation with temperatures, and that type of information could be news to the typical reader as well. In other words, you could emphasize the areas where you all agree with IPCC/NCA/etc, which in turn would help anchor this report to the consensus view. That borders on a political or public affairs consideration, I know, so please feel free to ignore it completely.

3) I can see why the Secretary chose this team. You all are world-class experts. It's been a privilege to watch this report come together, and I'll do everything in my power to make it something you all can be proud of. If you want me to add comment bubbles to flag areas where the non-expert might trip up, I'd be happy to do

that. Or if there's anything else I can do aside from the next glossary and the cover letter from the Secretary (and coordination with EPA), please let me know.

4) I took too long to hit send on this email, and I see a new one from Judy. +1 to Judy's point about leaving evaluations and judgments out of the body of the report. I may also try to flag areas where I see opinions or the inevitable pejorative. Personally, I had no idea how slick some of the NCA findings were in terms of narrowly defining the state of the climate to generate the appearance of a crisis, and I have become a new level of cynical after seeing it more clearly, thanks to you all. I'm excited to see the much-needed conversations this report will generate.

Best,
Travis

On Sun, May 11, 2025 at 11:06 AM Judith Curry <curry.judith@gmail.com> wrote:

Well the point of JC and RS analyses later in the chapter demonstrate the importance of looking back prior to 1950. And i think we should stick to conclusion statements in the SPM and Chapter summaries, rather than the text of the report that cites primary references (that looks like cherry picking). And AR6 is the main doc driving policy arguments; i don't think EPA lawyers are going to go back to AR5

On Sun, May 11, 2025 at 7:38 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

My concerns are that these excerpts leave out too much valuable material and that they lead with the AR6 cherry-picked 1950s as the starting point for trends. Both with respect to heatwaves and precip the only way to detect increases is to compare back to the 50s. If they include the 1930s or further back the heatwave picture falls apart, and as we show further in the chapter the precip picture falls apart either starting in the 70s or the 1800s. This selection puts us in a weak position where we will appear to be arguing against IPCC assessments using our own data, even though the more complete survey shows that our data aligns with what the assessments have been saying all along.

One reason to include material from the past assessment reports is that people have been hearing a narrative about extreme weather for 20+ years. A brief survey won't suffice to overcome the cognitive dissonance we're up against in this chapter. The comprehensive survey of IPCC and NCA material is the only way to overcome it. If we only show the AR6 they might think that's somehow new whereas prior reports said something else. I want to show convincingly that the message today is about the same as it's always been.

For those of us who know what the IPCC says and has said in the past it might seem tedious to quote it at such length. But I've presented to enough undergrad classes and public audiences to know that people don't find these quotes boring, they find them incredible. If it's a question of chapter order I don't mind if there's a brief preface then the whole collection goes into the chapter appendix, but I see no benefit to omitting the material and considerable gain from including it. And I still think the best option is to lead with it.

What say others?

On Sat, May 10, 2025 at 5:55 PM Judith Curry <curry.judith@gmail.com> wrote:

See attached for my smash down of section 8.2 (13 down to 2 pages). I included on detection statements (no attribution or projections); focused on AR6 and included some statements from NCA17 and SREX

that provided additional detail. I focused on summary statements from the SPM and chapter summaries (without citations of individual papers)

Let me know what you think, and whether you prefer it up front or at the end (maybe an appendix)

On Sat, May 10, 2025 at 11:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:
I like John's suggestion.

Steven E. Koonin

On May 10, 2025, at 14:36, John Christy <climateman60@gmail.com> wrote:

Judy

Would this work. Put the IPCC/NCA quotes in bold up front with a little introductory remark then add "full statements in context in appendix"?

John C.

Sent from my iPhone

On May 10, 2025, at 5:49 AM, Judith Curry <curry.judith@gmail.com> wrote:

I'm working on CH 8 Extreme Weather front end today, more soon

On Sat, May 10, 2025 at 8:37 AM Steven Koonin
<steven.koonin@gmail.com> wrote:

Yes! In the exec summary and the chapter preface we must repeat something like "Contrary to popular perception..."

Steven E. Koonin

On May 10, 2025, at 11:19, Ross McKittrick
<ross.mckittrick@gmail.com> wrote:

This just appeared in the Daily Mail
<https://www.dailymail.co.uk/sciencetech/article-14686539/climate-change-affect-YOU-heatwaves-floods.html>

The extreme weather alarmism angle has been non-stop for years. People are saturated with the message that

climate change = extreme weather and all scientists say it's bad and getting worse due to GHGs. It will take a lot of hammering on the theme to convince people how much they've been misled. So I don't mind if the first 15 pages of this chapter consists of mind-numbing repetition of the message that scientists don't say this and have never said it. At this point I want to hold the readers' faces in it until their limbs stop twitching and then they'll be receptive to the rest of the material.

On Fri, May 9, 2025 at 3:09 PM Judith Curry

<curry.judith@gmail.com> wrote:

I agree we should have something up front, but not pages. Will propose something more specific

On Fri, May 9, 2025 at 12:06 PM Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

My read of the discussion on May 8 was that Steve made a strong pitch to move the survey back up front and you and Roy concurred. I'll let you guys debate it.

On Fri, May 9, 2025 at 3:01 PM Judith Curry

<curry.judith@gmail.com> wrote:

actually no, i thought we left this as an appendix or something (i don't think it is necessary tho). We need some sort of a summary on what the IPCC found

I have this para in the attribution chapter

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table 12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most regions in the mid-latitudes, medium confidence elsewhere
- Medium confidence in a decrease in extreme cold events in Australia, Africa and most of northern South America where observations allow trend estimation
- No evidence of emergence in the historical period of a change in river floods, heavy precipitation, drought, fire weather, severe wind storms, and tropical cyclones

On Fri, May 9, 2025 at 11:55 AM Ross McKittrick
<ross.mckittrick@gmail.com> wrote:

I thought you said (May 8) you liked the suggestion to move them all back to the front.

On Fri, May 9, 2025 at 2:52 PM Judith Curry
<curry.judith@gmail.com> wrote:

I don't like having pages of IPCC/NCA citations (IMO the key issue is a lot of uncertainty and disagreement, and the inconsistency between chapters 11 and 12 of AR6). If we do include a shortened version of this, i would focus only on AR6, either global or US region.

On Fri, May 9, 2025 at 11:45 AM Ross McKittrick
<ross.mckittrick@gmail.com> wrote:

In the attached Extreme Weather chapter draft I moved the IPCC/NCA excerpts back into the main body per the discussion here and renumbered all the sections and figures mutatis mutandis.

The AI summary is not bad but does need some work. Admittedly it's a lot of stuff to summarize, although the recurring theme is that trends aren't detectable and attribution to GHGs is currently not possible, in general.

On Thu, May 8, 2025 at 1:45 PM Roy Spencer
<roywspencer@hotmail.com> wrote:

This way forward is fine with me.

-Roy

From: Judith Curry <curry.judith@gmail.com>
Sent: Thursday, May 8, 2025 12:43 PM
To: John Christy <climateman60@gmail.com>
Cc: Steven Koonin <steven.koonin@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Subject: Re: Ch 8 Extreme weather

I think starting with IPCC up front is very useful to provide a reference point, and discussing problems with NCA motivates the unpublished data analysis

On Thu, May 8, 2025 at 10:36 AM John Christy <climateman60@gmail.com> wrote:

Ultimately the order will likely not matter. We are somewhat conflicted. On one hand we show the Assessments are consistent with our conclusions about extreme weather, but on the other hand we find them (especially NCAs) deceptive in presenting the information that skews their results to lean toward alarmism. This is true of other chapters as well.

At the least we should mention this nuance perhaps up front.

John C.

Sent from my iPhone

On May 8, 2025, at 6:23 AM,
Judith Curry
<curry.judith@gmail.com> wrote:

I also agree with this organization,
was thinking the same thing

On Thu, May 8, 2025 at 8:52 AM
Steven Koonin
<steven.koonin@gmail.com>
wrote:

Attached are my comments/edits on
Chapter 8.

I'd like to make a strong pitch to reorder the text so that the survey of previous assessments comes first, then followed by the new work from John and Ross. There are several reasons for this that I can elaborate, but the most important is that the official assessments already make the case and, no offense guys, carry far more authority in the non-expert world.

SEK

PS Note for interest and amusement the AI-generated summary section.

From: Ross McKittrick
<ross.mckittrick@gmail.com>
Sent: Tuesday, May 6, 2025 1:05 PM
To: John Christy
<climateman60@gmail.com>
Cc: Judith Curry
<curry.judith@gmail.com>; Roy W. Spencer
<roywspencer@hotmail.com>;
Travis Fisher
<travis.scott.fisher@gmail.com>;
Steven Koonin
<steven.koonin@gmail.com>
Subject: Re: Ch 8 Extreme weather

Here's another edition of Ch 8 on extremes taking Judy's and John's points into account. The IPCC/NCA review is ported to an Appendix. I added a paragraph about LTP to the intro. I've incorporated the NE data. The bulk of the chapter is John's US temperature and precip data analysis with some additional material on wildfires, drought and TCs. For the US temperature

extremes I moved the range figure to come just after the hot/cold extremes count because I think they both make a coherent point namely that the US becoming less extreme because heat events are rising more slowly than cold events are warming. There will still need to be an overall chapter summary but I'm going to move on to other chapters now. I'll put this in the Dropbox.

On Tue, May 6, 2025 at 12:12 PM
John Christy
<climateman60@gmail.com>
wrote:

All

We can fill in without much trouble the change, or lack thereof, of “high impact” weather events (mainly wind and flooding like hurricanes, tornadoes etc) in the CONUS Extreme chapter. The temp and precip metrics are important because they are just long enough to essentially tell us Mother Nature has a mind of her own.

1. I'll look at Ross's version of 8 soon, but my hope was that Ross would translate the statistical remarks into the correct language(eg are their more precise words that chaotic, episodic, stochastic, etc).

2. We have analyses of the CONUS with more complete datasets than the NCA used (recall NCA analyses depended essentially on a small group at NCEI using datasets that (a) were not very consistent in time, (b) could promote alarm and (c) already easy for them to get to. Our datasets have literally hundreds of thousands of manually keyed-in observations for temporal consistency. In other words, this lets people know we can address these issues from soup to nuts - we're not armchair climate scientists ... we can reproduce what they did, but make the analysis more comprehensive to address the questions.

John C.

Sent from my iPhone

On May 6, 2025,
at 4:14 AM, Ross
McKittrick

<ross.mckittrick@gmail.com>
wrote:

Just read your
attribution
chapter. I hadn't
picked up on the
gap between

IPCC Ch 11 vs
Ch 12 language
but i see your
point that rather
than promoting
one set of
attribution
findings we
should explain
that even within
the same AR
different authors
assessed things
differently. One
option is to leave
Ch 6 where it is
but reverse the
order of Ch 7 and
8 while retitling
the latter as you
suggest. That
way, having
established the
extreme weather
types for which
there are no
detectable trends
it will more
naturally follow
that they won't be
discussed in the
attribution
chapter.

On Tue, May 6,
2025 at 9:45 AM
Judith Curry
<curry.judith@gmail.com>
curry.judith@gmail.com> wrote:

Ok, but the
summary table
(12.12 from
AR6) is
inconsistent with
conclusions in
AR6 ch 11 (I

point this out in section 6.4 of my attribution chapter).

In my mind, the main point is disagreement and ambiguity I would suggest chapter 8 going before chapter 6, retitling it as US Weather and Climate Extremes, and make it more of a data chapter, not an attribution chapter (I would put table 12.12 in the attribution chapter if you want to include the actual table)

On Tue, May 6, 2025 at 6:39 AM
Ross McKittrick
<ross.mckittrick@gmail.com>
wrote:

I like john's material too which is why I included it and am working on the extended regional analyses. But on this topic people are heavily primed to believe that extreme weather of all

kinds is getting worse due to climate change. The assertion shows up everywhere climate change is discussed including in academic papers. I think it is very valuable to show people that neither the IPCC nor the NCA support such this view. We should at least lead off with the summary table. The library of quotes can go to an appendix but I have found in my public speaking that they have considerable persuasive force for most people. We also need to address floods, droughts, hurricane landfalls, tornadoes etc. I don't see any reason to delete all that material.

On Tue, May 6,
2025 at
9:22 AM Judith
Curry
<curry.judith@gmail.com>
wrote:

I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes"

I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable severe weather event.

John's version meshes very well with my version of chapter 6. Read especially section 6.4 of my chapter. I note a discrepancy between chapters 11 and 12 in terms of detecting and attributing extreme events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the

problems/challenges, and topics that are particularly relevant for the US

On Mon, May 5, 2025 at 7:47 PM Ross McKittrick <ross.mckitrick@gmail.com> wrote:

I have wrangled the extreme weather chapter into something I hope flows better and is more readable. I adopted Judy's editorial changes and then the new changes I made are in red. I added some new Figures showing results on PC and SE data and will add the NE chart when I get the data. I also made some labeling suggestions

including for
the 3 rainfall
charts that are
hard to
understand.
Section
summaries
and an overall
summary are
still needed.

Ross

--

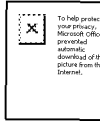
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Judith Curry, President
CFAN - Climate Forecast Applications Netw
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.
<http://www.cfanclimate.net>

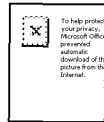
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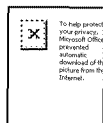
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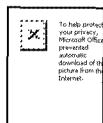
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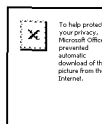
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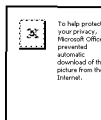
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From: Roy Spencer <roywspencer@hotmail.com>
Sent: Sunday, May 11, 2025 4:49 PM
To: Ross McKittrick
Cc: Travis Fisher; Judith Curry; Steven Koonin; John Christy
Subject: RE: Ch 8 Extreme weather

Not sure whether the 1950s start comment was related to my tornadoes comment... US tornado stats didn't start until the 1950s. I was responding to Travis' query about severe convective storms.

-Roy

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: Ross McKittrick <ross.mckittrick@gmail.com>
Date: 5/11/25 3:27 PM (GMT-06:00)
To: Roy Spencer <roywspencer@hotmail.com>
Cc: Travis Fisher <travis.scott.fisher@gmail.com>, Judith Curry <curry.judith@gmail.com>, Steven Koonin <steven.koonin@gmail.com>, John Christy <climateman60@gmail.com>
Subject: Re: Ch 8 Extreme weather

I originally assembled the set of quotations for counsel in a Canadian court case pre-AR6, then showed it to lawyers in a different court case and too they thought it was very useful, and asked me to add AR6 material to it. So I wouldn't make a decision based on what we think lawyers might need or want.

The fact that later in the chapter we demonstrate the importance of looking pre-1950 confirms the point that we shouldn't lead with IPCC Summary statements based on post-1950 trends. And we're not limited to using SPM statements especially ones we plan to rebut.

On Sun, May 11, 2025 at 3:59 PM Roy Spencer <roywspencer@hotmail.com> wrote:

Regarding tornadoes, strong to intense tornadoes in the US are down 50%, probably due to fewer Canadian cold air outbreaks over the western US in spring. Not sure whether anyone has added that yet. Severe thunderstorms require wind shear which is a function of cold and warm air masses, which is a mid-latitude issue. Instead, physicists and maths folks think it's thermodynamic buoyant energy that's important but if that was true the tropics would be full of severe thunderstorms.

-Roy

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: Travis Fisher <travis.scott.fisher@gmail.com>

Date: 5/11/25 12:23 PM (GMT-06:00)

To: Judith Curry <curry.judith@gmail.com>

Cc: Ross McKittrick <ross.mckittrick@gmail.com>, Steven Koonin <steven.koonin@gmail.com>, John Christy <climatemanager60@gmail.com>, "Roy W. Spencer" <roywspencer@hotmail.com>

Subject: Re: Ch 8 Extreme weather

Will do. Apologies for the rambling email... I was trying to write with a kid on my lap. Just know I'm here to help!

On Sun, May 11, 2025 at 11:53 AM Judith Curry <curry.judith@gmail.com> wrote:

Travis, your comments on readability, gaps and red flag statements would be VERY helpful. The chapters all have a complete draft, but some are still in flux

On Sun, May 11, 2025 at 8:15 AM Travis Fisher <travis.scott.fisher@gmail.com> wrote:

As the non-expert member of the team, one of my contributions could be to provide input from the point of view of a reader who doesn't live and breathe these materials on a daily basis. With that in mind, I have a few observations that might help:

- 1) That said, I see no problem with adding more material. If the team is torn between the short version and the long version of any chapter, my preference is to leave more material and leave it to the reader whether to dig in or skim. We don't exactly have a word or page limit on this. Also, the point about cherry-picking starting points for the data is very compelling to me. It reminds me of the first time I saw the chart of air pollution data with reference to EPA's formation. Of course the trend is sharply down for criteria pollutants after 1970, but it was on a similar trend *before* 1970 as well. Those types of data-based expositions can be very powerful in refuting common misunderstandings.
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- 3) I can see why the Secretary chose this team. You all are world-class experts. It's been a privilege to watch this report come together, and I'll do everything in my power to make it something you all can be proud of. If you want me to add comment bubbles to flag areas where the non-expert might trip up, I'd be happy to do that. Or if there's anything else I can do aside from the next glossary and the cover letter from the Secretary (and coordination with EPA), please let me know.
- 4) I took too long to hit send on this email, and I see a new one from Judy. +1 to Judy's point about leaving evaluations and judgments out of the body of the report. I may also try to flag areas where I see opinions or the inevitable pejorative. Personally, I had no idea how slick some of the NCA findings were in terms of narrowly defining the state of the climate to generate the appearance of a crisis, and I have become a new

level of cynical after seeing it more clearly, thanks to you all. I'm excited to see the much-needed conversations this report will generate.

Best,
Travis

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One reason to include material from the past assessment reports is that people have been hearing a narrative about extreme weather for 20+ years. A brief survey won't suffice to overcome the cognitive dissonance we're up against in this chapter. The comprehensive survey of IPCC and NCA material is the only way to overcome it. If we only show the AR6 they might think that's somehow new whereas prior reports said something else. I want to show convincingly that the message today is about the same as it's always been.

For those of us who know what the IPCC says and has said in the past it might seem tedious to quote it at such length. But I've presented to enough undergrad classes and public audiences to know that people don't find these quotes boring, they find them incredible. If it's a question of chapter order I don't mind if there's a brief preface then the whole collection goes into the chapter appendix, but I see no benefit to omitting the material and considerable gain from including it. And I still think the best option is to lead with it.

What say others?

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Steven E. Koonin

On May 10, 2025, at 14:36, John Christy <climateman60@gmail.com> wrote:

Judy

Would this work. Put the IPCC/NCA quotes in bold up front with a little introductory remark then add “full statements in context in appendix”?

John C.

Sent from my iPhone

On May 10, 2025, at 5:49 AM, Judith Curry <curry.judith@gmail.com> wrote:

I'm working on CH 8 Extreme Weather front end today, more soon

On Sat, May 10, 2025 at 8:37 AM Steven Koonin
<steven.koonin@gmail.com> wrote:

Yes! In the exec summary and the chapter preface we must repeat something like “Contrary to popular perception...”

Steven E. Koonin

On May 10, 2025, at 11:19, Ross McKittrick
<ross.mckittrick@gmail.com> wrote:

This just appeared in the Daily Mail
<https://www.dailymail.co.uk/sciencetech/article-14686539/climate-change-affect-YOU-heatwaves-floods.html>

The extreme weather alarmism angle has been non-stop for years. People are saturated with the message that climate change = extreme weather and all scientists say it's bad and getting worse due to GHGs. It will take a lot of hammering on the theme to convince people how much they've been misled. So I don't mind if the first 15 pages of this chapter consists of mind-numbing repetition of the message that scientists don't say this and have never said it. At this point I want to hold the readers' faces in it until their limbs stop twitching and then they'll be receptive to the rest of the material.

On Fri, May 9, 2025 at 3:09 PM Judith Curry

<curry.judith@gmail.com> wrote:

I agree we should have something up front, but not pages. Will propose something more specific

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<ross.mckittrick@gmail.com> wrote:

My read of the discussion on May 8 was that Steve made a strong pitch to move the survey back up front and you and Roy concurred. I'll let you guys debate it.

On Fri, May 9, 2025 at 3:01 PM Judith Curry

<curry.judith@gmail.com> wrote:

actually no, i thought we left this as an appendix or something (i don't think it is necessary tho). We need some sort of a summary on what the IPCC found

I have this para in the attribution chapter

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most

regions in the mid-latitudes, medium confidence elsewhere

- Medium confidence in a decrease in extreme cold events in Australia, Africa and most of northern South America where observations allow trend estimation
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I thought you said (May 8) you liked the suggestion to move them all back to the front.

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<curry.judith@gmail.com> wrote:

I don't like having pages of IPCC/NCA citations (IMO the key issue is a lot of uncertainty and disagreement, and the inconsistency between chapters 11 and 12 of AR6). If we do include a shortened version of this, i would focus only on AR6, either global or US region.

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In the attached Extreme Weather chapter draft I moved the IPCC/NCA excerpts back into the main body per the discussion here and renumbered all the sections and figures mutatis mutandis.

The AI summary is not bad but does need some work. Admittedly it's a lot of stuff to summarize, although the recurring theme is that trends aren't detectable and attribution to GHGs is currently not possible, in general.

On Thu, May 8, 2025 at 1:45 PM Roy Spencer

<roywspencer@hotmail.com> wrote:

This way forward is fine with me.

-Roy

From: Judith Curry <curry.judith@gmail.com>

Sent: Thursday, May 8, 2025 12:43 PM

To: John Christy <climateman60@gmail.com>

Cc: Steven Koonin <steven.koonin@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher

<travis.scott.fisher@gmail.com>

Subject: Re: Ch 8 Extreme weather

I think starting with IPCC up front is very useful to provide a reference point, and discussing problems with NCA motivates the unpublished data analysis

On Thu, May 8, 2025 at 10:36 AM John Christy

<climateman60@gmail.com> wrote:

Ultimately the order will likely not matter. We are somewhat conflicted. On one hand we show the Assessments are consistent with our conclusions about extreme weather, but on the other hand we find them (especially NCAs) deceptive in presenting the information that skews their results to lean toward alarmism. This is true of other chapters as well.

At the least we should mention this nuance perhaps up front.

John C.

Sent from my iPhone

On May 8, 2025, at 6:23 AM, Judith Curry <curry.judith@gmail.com> wrote:

I also agree with this organization, was thinking the same thing

On Thu, May 8, 2025 at 8:52 AM

Steven Koonin

<steven.koonin@gmail.com>

wrote:

Attached are my comments/edits on Chapter 8.

I'd like to make a strong pitch to reorder the text so that the survey of previous assessments comes first, then followed by the new work from John and Ross. There are several reasons for this that I can elaborate, but the most important is that the official assessments already make the case

and, no offense guys, carry far more authority in the non-expert world.

SEK

PS Note for interest and amusement the AI-generated summary section.

From: Ross McKittrick
<ross.mckittrick@gmail.com>
Sent: Tuesday, May 6, 2025 1:05 PM
To: John Christy
<climateman60@gmail.com>
Cc: Judith Curry
<curry.judith@gmail.com>; Roy W. Spencer
<roywspencer@hotmail.com>; Travis Fisher
<travis.scott.fisher@gmail.com>; Steven Koonin
<steven.koonin@gmail.com>
Subject: Re: Ch 8 Extreme weather

Here's another edition of Ch 8 on extremes taking Judy's and John's points into account. The IPCC/NCA review is ported to an Appendix. I added a paragraph about LTP to the intro. I've incorporated the NE data. The bulk of the chapter is John's US temperature and precip data analysis with some additional material on wildfires, drought and TCs. For the US temperature extremes I moved the range figure to come just after the hot/cold extremes count because I think they both make a coherent point namely that the US becoming less extreme because heat events are rising more slowly than cold events are warming. There will still need to be an overall

chapter summary but I'm going to move on to other chapters now. I'll put this in the Dropbox.

On Tue, May 6, 2025 at 12:12 PM
John Christy
<climateman60@gmail.com>
wrote:

All

We can fill in without much trouble the change, or lack thereof, of “high impact” weather events (mainly wind and flooding like hurricanes, tornadoes etc) in the CONUS Extreme chapter. The temp and precip metrics are important because they are just long enough to essentially tell us Mother Nature has a mind of her own.

1. I'll look at Ross's version of 8 soon, but my hope was that Ross would translate the statistical remarks into the correct language(eg are their more precise words that chaotic, episodic, stochastic, etc).

2. We have analyses of the CONUS with more complete datasets than the NCA used (recall NCA analyses depended essentially on a small group at NCEI using datasets that (a) were not very consistent in time, (b) could promote alarm and (c) already easy for them to get to. Our datasets have literally

hundreds of thousands of manually keyed-in observations for temporal consistency. In other words, this lets people know we can address these issues from soup to nuts - we're not armchair climate scientists ... we can reproduce what they did, but make the analysis more comprehensive to address the questions.

John C.

Sent from my iPhone

On May 6, 2025, at
4:14 AM, Ross
McKittrick

<ross.mckittrick@gmail.com> wrote:

Just read your attribution chapter. I hadn't picked up on the gap between IPCC Ch 11 vs Ch 12 language but i see your point that rather than promoting one set of attribution findings we should explain that even within the same AR different authors assessed things differently.

One option is to leave Ch 6 where it is but reverse the order of Ch 7 and 8 while retitling the latter as you suggest. That way, having established the extreme weather types for which there are no detectable trends it will more naturally follow that they won't be discussed in the attribution chapter.

On Tue, May 6,
2025 at 9:45 AM
Judith Curry
<curry.judith@gmail.com> wrote:

Ok, but the summary table (12.12 from AR6) is inconsistent with conclusions in AR6 ch 11 (I point this out in section 6.4 of my attribution chapter).

In my mind, the main point is disagreement and ambiguity I would suggest chapter 8 going before chapter 6, retitling it as US

Weather and
Climate
Extremes, and
make it more of a
data chapter, not
an attribution
chapter (I would
put table 12.12 in
the attribution
chapter if you
want to include
the actual table)

On Tue, May 6,
2025 at 6:39 AM
Ross McKittrick
<[ross.mckittrick@
gmail.com](mailto:ross.mckittrick@gmail.com)>
wrote:

I like john's
material too
which is why I
included it and
am working
on the extended
regional
analyses. But on
this topic people
are heavily
primed to believe
that extreme
weather of all
kinds is getting
worse due to
climate change.
The assertion
shows up
everywhere
climate change is
discussed
including in
academic papers.
I think it is very
valuable to show
people that
neither the IPCC
nor the NCA
support such this

view. We should at least lead off with the summary table. The library of quotes can go to an appendix but I have found in my public speaking that they have considerable persuasive force for most people. We also need to address floods, droughts, hurricane landfalls, tornadoes etc. I don't see any reason to delete all that material.

On Tue, May 6,
2025 at 9:22 AM
Judith Curry
<curry.judith@gmail.com>
wrote:

I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes"

I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable

severe weather
event.

John's version
meshes very
well with my
version of
chapter 6. Read
especially
section 6.4 of
my chapter. I
note a
discrepancy
between
chapters 11 and
12 in terms of
detecting and
attributing
extreme
events. This is
the main point
in my opinion,
there is
ambiguity in all
this. Lets focus
on pointing out
the
problems/challe
nges, and topics
that are
particularly
relevant for the
US

On Mon, May
5, 2025 at
7:47 PM Ross
McKitrick
<ross.mckitrick@gmail.com>
wrote:

I have
wrangled the
extreme
weather
chapter into
something I
hope flows
better and is
more readable.
I adopted
Judy's editorial
changes and
then the new
changes I
made are in
red. I added
some new
Figures
showing result
s on PC and
SE data and
will add the
NE chart when
I get the data. I
also made
some labeling
suggestions
including for
the 3 rainfall
charts that are
hard to
understand.
Section
summaries and
an overall
summary are
still needed.

Ross

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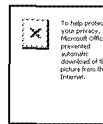
Judith Curry, President
CFAN - Climate Forecast Applications Netw
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803
<http://www.cfanclimate.net>

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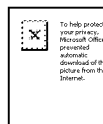
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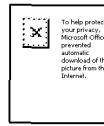


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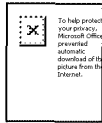


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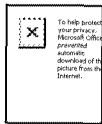
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From: Ross McKittrick <ross.mckitrick@gmail.com>
Sent: Sunday, May 11, 2025 4:27 PM
To: Roy Spencer
Cc: Travis Fisher; Judith Curry; Steven Koonin; John Christy
Subject: Re: Ch 8 Extreme weather

I originally assembled the set of quotations for counsel in a Canadian court case pre-AR6, then showed it to lawyers in a different court case and too they thought it was very useful, and asked me to add AR6 material to it. So I wouldn't make a decision based on what we think lawyers might need or want.

The fact that later in the chapter we demonstrate the importance of looking pre-1950 confirms the point that we shouldn't lead with IPCC Summary statements based on post-1950 trends. And we're not limited to using SPM statements especially ones we plan to rebut.

On Sun, May 11, 2025 at 3:59 PM Roy Spencer <roywspencer@hotmail.com> wrote:

Regarding tornadoes, strong to intense tornadoes in the US are down 50%, probably due to fewer Canadian cold air outbreaks over the western US in spring. Not sure whether anyone has added that yet. Severe thunderstorms require wind shear which is a function of cold and warm air masses, which is a mid-latitude issue. Instead, physicists and maths folks think it's thermodynamic buoyant energy that's important but if that was true the tropics would be full of severe thunderstorms.

-Roy

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: Travis Fisher <travis.scott.fisher@gmail.com>
Date: 5/11/25 12:23 PM (GMT-06:00)
To: Judith Curry <curry.judith@gmail.com>
Cc: Ross McKittrick <ross.mckitrick@gmail.com>, Steven Koonin <steven.koonin@gmail.com>, John Christy <climatemanager60@gmail.com>, "Roy W. Spencer" <roywspencer@hotmail.com>
Subject: Re: Ch 8 Extreme weather

Will do. Apologies for the rambling email... I was trying to write with a kid on my lap. Just know I'm here to help!

On Sun, May 11, 2025 at 11:53 AM Judith Curry <curry.judith@gmail.com> wrote:

Travis, your comments on readability, gaps and red flag statements would be VERY helpful. The chapters all have a complete draft, but some are still in flux

On Sun, May 11, 2025 at 8:15 AM Travis Fisher <travis.scott.fisher@gmail.com> wrote:

As the non-expert member of the team, one of my contributions could be to provide input from the point of view of a reader who doesn't live and breathe these materials on a daily basis. With that in mind, I have a few observations that might help:

1) That said, I see no problem with adding more material. If the team is torn between the short version and the long version of any chapter, my preference is to leave more material and leave it to the reader whether to dig in or skim. We don't exactly have a word or page limit on this. Also, the point about cherry-picking starting points for the data is very compelling to me. It reminds me of the first time I saw the chart of air pollution data with reference to EPA's formation. Of course the trend is sharply down for criteria pollutants after 1970, but it was on a similar trend *before* 1970 as well. Those types of data-based expositions can be very powerful in refuting common misunderstandings.

2) Some of the issues you all know incredibly well could use more elaboration for the uninitiated reader, especially when you agree fully with the consensus, IPCC, or NCA view. As one example, I was looking for more info on convective events in the extreme weather chapter. I know they are covered briefly, but my reaction as the non-expert was surprise at how little focus the consensus view gives them (and how lightly that fact was discussed in your chapter). I think we should emphasize the areas where, at least according to a typical reading of the news and popular narratives, climate change is blamed for things that aren't even on an upward trend. Thunderstorms and hailstorms are certainly part of that narrative. I'm less familiar with tornadoes entering the narrative, but it was news to me that there is essentially zero correlation with temperatures, and that type of information could be news to the typical reader as well. In other words, you could emphasize the areas where you all agree with IPCC/NCA/etc, which in turn would help anchor this report to the consensus view. That borders on a political or public affairs consideration, I know, so please feel free to ignore it completely.

3) I can see why the Secretary chose this team. You all are world-class experts. It's been a privilege to watch this report come together, and I'll do everything in my power to make it something you all can be proud of. If you want me to add comment bubbles to flag areas where the non-expert might trip up, I'd be happy to do that. Or if there's anything else I can do aside from the next glossary and the cover letter from the Secretary (and coordination with EPA), please let me know.

4) I took too long to hit send on this email, and I see a new one from Judy. +1 to Judy's point about leaving evaluations and judgments out of the body of the report. I may also try to flag areas where I see opinions or the inevitable pejorative. Personally, I had no idea how slick some of the NCA findings were in terms of narrowly defining the state of the climate to generate the appearance of a crisis, and I have become a new level of cynical after seeing it more clearly, thanks to you all. I'm excited to see the much-needed conversations this report will generate.

Best,
Travis

On Sun, May 11, 2025 at 11:06 AM Judith Curry <curry.judith@gmail.com> wrote:

Well the point of JC and RS analyses later in the chapter demonstrate the importance of looking back prior to 1950. And i think we should stick to conclusion statements in the SPM and Chapter summaries, rather than the text of the report that cites primary references (that looks like cherry picking). And AR6 is the main doc driving policy arguments; i don't think EPA lawyers are going to go back to AR5

On Sun, May 11, 2025 at 7:38 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

My concerns are that these excerpts leave out too much valuable material and that they lead with the AR6 cherry-picked 1950s as the starting point for trends. Both with respect to heatwaves and precip the only way to detect increases is to compare back to the 50s. If they include the 1930s or further back the heatwave picture falls apart, and as we show further in the chapter the precip picture falls apart either starting in the 70s or the 1800s. This selection puts us in a weak position where we will appear to be

arguing against IPCC assessments using our own data, even though the more complete survey shows that our data aligns with what the assessments have been saying all along.

One reason to include material from the past assessment reports is that people have been hearing a narrative about extreme weather for 20+ years. A brief survey won't suffice to overcome the cognitive dissonance we're up against in this chapter. The comprehensive survey of IPCC and NCA material is the only way to overcome it. If we only show the AR6 they might think that's somehow new whereas prior reports said something else. I want to show convincingly that the message today is about the same as it's always been.

For those of us who know what the IPCC says and has said in the past it might seem tedious to quote it at such length. But I've presented to enough undergrad classes and public audiences to know that people don't find these quotes boring, they find them incredible. If it's a question of chapter order I don't mind if there's a brief preface then the whole collection goes into the chapter appendix, but I see no benefit to omitting the material and considerable gain from including it. And I still think the best option is to lead with it.

What say others?

On Sat, May 10, 2025 at 5:55 PM Judith Curry <curry.judith@gmail.com> wrote:

See attached for my smash down of section 8.2 (13 down to 2 pages). I included on detection statements (no attribution or projections); focused on AR6 and included some statements from NCA17 and SREX that provided additional detail. I focused on summary statements from the SPM and chapter summaries (without citations of individual papers)

Let me know what you think, and whether you prefer it up front or at the end (maybe an appendix)

On Sat, May 10, 2025 at 11:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:

I like John's suggestion.

Steven E. Koonin

On May 10, 2025, at 14:36, John Christy <climateman60@gmail.com> wrote:

Judy

Would this work. Put the IPCC/NCA quotes in bold up front with a little introductory remark then add "full statements in context in appendix"?

John C.

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Steven E. Koonin

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The extreme weather alarmism angle has been non-stop for years. People are saturated with the message that climate change = extreme weather and all scientists say it's bad and getting worse due to GHGs. It will take a lot of hammering on the theme to convince people how much they've been misled. So I don't mind if the first 15 pages of this chapter consists of mind-numbing repetition of the message that scientists don't say this and have never said it. At this point I want to hold the readers' faces in it until their limbs stop twitching and then they'll be receptive to the rest of the material.

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I agree we should have something up front, but not pages. Will propose something more specific

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actually no, i thought we left this as an appendix or something (i don't think it is necessary tho). We need some sort of a summary on what the IPCC found

I have this para in the attribution chapter

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table 12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most regions in the mid-latitudes, medium confidence elsewhere
- Medium confidence in a decrease in extreme cold events in Australia, Africa and most of northern South America where observations allow trend estimation
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The AI summary is not bad but does need some work. Admittedly it's a lot of stuff to summarize, although the recurring theme is that trends aren't detectable and attribution to GHGs is currently not possible, in general.

On Thu, May 8, 2025 at 1:45 PM Roy Spencer

<roywspencer@hotmail.com> wrote:

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-Roy

From: Judith Curry <curry.judith@gmail.com>

Sent: Thursday, May 8, 2025 12:43 PM

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Ultimately the order will likely not matter. We are somewhat conflicted. On one hand we show the Assessments are consistent with our conclusions about extreme weather, but on the other hand we find them (especially NCAs) deceptive in presenting the information that skews their results to lean toward alarmism. This is true of other chapters as well.

At the least we should mention this nuance perhaps up front.

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I also agree with this organization, was thinking the same thing

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Attached are my comments/edits on Chapter 8.

I'd like to make a strong pitch to reorder the text so that the survey of previous assessments comes first, then followed by the new work from John and Ross. There are several reasons for this that I can elaborate, but the most important is that the official assessments already make the case and, no offense guys, carry far more authority in the non-expert world.

SEK

PS Note for interest and amusement the AI-generated summary section.

From: Ross McKittrick
<ross.mckittrick@gmail.com>
Sent: Tuesday, May 6, 2025 1:05 PM
To: John Christy

<climateman60@gmail.com>

Cc: Judith Curry

<curry.judith@gmail.com>; Roy W. Spencer

<roywspencer@hotmail.com>; Travis Fisher

<travis.scott.fisher@gmail.com>;

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Subject: Re: Ch 8 Extreme weather

Here's another edition of Ch 8 on extremes taking Judy's and John's points into account. The IPCC/NCA review is ported to an Appendix. I added a paragraph about LTP to the intro. I've incorporated the NE data. The bulk of the chapter is John's US temperature and precip data analysis with some additional material on wildfires, drought and TCs. For the US temperature extremes I moved the range figure to come just after the hot/cold extremes count because I think they both make a coherent point namely that the US becoming less extreme because heat events are rising more slowly than cold events are warming. There will still need to be an overall chapter summary but I'm going to move on to other chapters now. I'll put this in the Dropbox.

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We can fill in without much trouble the change, or lack thereof, of “high impact” weather events (mainly wind and flooding like hurricanes, tornadoes etc) in the CONUS Extreme chapter. The temp and precip metrics are important because they are just long enough to essentially tell us Mother Nature has a mind of her own.

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On Mon, May 5, 2025 at 7:47 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I have wrangled the extreme weather chapter into something I hope flows better and is more readable. I adopted Judy's editorial changes and then the new changes I made are in red. I added some new Figures

showing results on PC and SE data and will add the NE chart when I get the data. I also made some labeling suggestions including for the 3 rainfall charts that are hard to understand. Section summaries and an overall summary are still needed.

Ross

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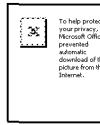
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Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2
<http://www.cfanclimate.net>

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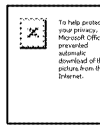
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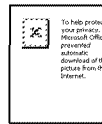
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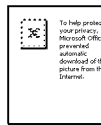
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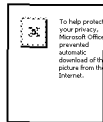
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From: Roy Spencer <roywspencer@hotmail.com>
Sent: Sunday, May 11, 2025 3:59 PM
To: Travis Fisher; Judith Curry
Cc: Ross McKittrick; Steven Koonin; John Christy
Subject: RE: Ch 8 Extreme weather

Regarding tornadoes, strong to intense tornadoes in the US are down 50%, probably due to fewer Canadian cold air outbreaks over the western US in spring. Not sure whether anyone has added that yet. Severe thunderstorms require wind shear which is a function of cold and warm air masses, which is a mid-latitude issue. Instead, physicists and maths folks think it's thermodynamic buoyant energy that's important but if that was true the tropics would be full of severe thunderstorms.

-Roy

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: Travis Fisher <travis.scott.fisher@gmail.com>
Date: 5/11/25 12:23 PM (GMT-06:00)
To: Judith Curry <curry.judith@gmail.com>
Cc: Ross McKittrick <ross.mckittrick@gmail.com>, Steven Koonin <steven.koonin@gmail.com>, John Christy <climateman60@gmail.com>, "Roy W. Spencer" <roywspencer@hotmail.com>
Subject: Re: Ch 8 Extreme weather

Will do. Apologies for the rambling email... I was trying to write with a kid on my lap. Just know I'm here to help!

On Sun, May 11, 2025 at 11:53 AM Judith Curry <curry.judith@gmail.com> wrote:

Travis, your comments on readability, gaps and red flag statements would be VERY helpful. The chapters all have a complete draft, but some are still in flux

On Sun, May 11, 2025 at 8:15 AM Travis Fisher <travis.scott.fisher@gmail.com> wrote:

As the non-expert member of the team, one of my contributions could be to provide input from the point of view of a reader who doesn't live and breathe these materials on a daily basis. With that in mind, I have a few observations that might help:

1) That said, I see no problem with adding more material. If the team is torn between the short version and the long version of any chapter, my preference is to leave more material and leave it to the reader whether to dig in or skim. We don't exactly have a word or page limit on this. Also, the point about cherry-picking starting points for the data is very compelling to me. It reminds me of the first time I saw the chart of air pollution data with reference to EPA's formation. Of course the trend is sharply down for criteria pollutants after 1970, but it was on a similar trend *before* 1970 as well. Those types of data-based expositions can be very powerful in refuting common misunderstandings.

2) Some of the issues you all know incredibly well could use more elaboration for the uninitiated reader, especially when you agree fully with the consensus, IPCC, or NCA view. As one example, I was looking for more info on convective events in the extreme weather chapter. I know they are covered briefly, but my reaction as the non-expert was surprise at how little focus the consensus view gives them (and how lightly that fact was discussed in your chapter). I think we should emphasize the areas where, at least according to a typical reading of the news and popular narratives, climate change is blamed for things that aren't even on an upward trend. Thunderstorms and hailstorms are certainly part of that narrative. I'm less familiar with tornadoes entering the narrative, but it was news to me that there is essentially zero correlation with temperatures, and that type of information could be news to the typical reader as well. In other words, you could emphasize the areas where you all agree with IPCC/NCA/etc, which in turn would help anchor this report to the consensus view. That borders on a political or public affairs consideration, I know, so please feel free to ignore it completely.

3) I can see why the Secretary chose this team. You all are world-class experts. It's been a privilege to watch this report come together, and I'll do everything in my power to make it something you all can be proud of. If you want me to add comment bubbles to flag areas where the non-expert might trip up, I'd be happy to do that. Or if there's anything else I can do aside from the next glossary and the cover letter from the Secretary (and coordination with EPA), please let me know.

4) I took too long to hit send on this email, and I see a new one from Judy. +1 to Judy's point about leaving evaluations and judgments out of the body of the report. I may also try to flag areas where I see opinions or the inevitable pejorative. Personally, I had no idea how slick some of the NCA findings were in terms of narrowly defining the state of the climate to generate the appearance of a crisis, and I have become a new level of cynical after seeing it more clearly, thanks to you all. I'm excited to see the much-needed conversations this report will generate.

Best,
Travis

On Sun, May 11, 2025 at 11:06 AM Judith Curry <curry.judith@gmail.com> wrote:

Well the point of JC and RS analyses later in the chapter demonstrate the importance of looking back prior to 1950. And i think we should stick to conclusion statements in the SPM and Chapter summaries, rather than the text of the report that cites primary references (that looks like cherry picking). And AR6 is the main doc driving policy arguments; i don't think EPA lawyers are going to go back to AR5

On Sun, May 11, 2025 at 7:38 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

My concerns are that these excerpts leave out too much valuable material and that they lead with the AR6 cherry-picked 1950s as the starting point for trends. Both with respect to heatwaves and precip the only way to detect increases is to compare back to the 50s. If they include the 1930s or further back the heatwave picture falls apart, and as we show further in the chapter the precip picture falls apart either starting in the 70s or the 1800s. This selection puts us in a weak position where we will appear to be arguing against IPCC assessments using our own data, even though the more complete survey shows that our data aligns with what the assessments have been saying all along.

One reason to include material from the past assessment reports is that people have been hearing a narrative about extreme weather for 20+ years. A brief survey won't suffice to overcome the cognitive dissonance we're up against in this chapter. The comprehensive survey of IPCC and NCA material is the only way to overcome it. If we only show the AR6 they might think that's somehow new whereas prior reports said something else. I want to show convincingly that the message today is about the same as it's always been.

For those of us who know what the IPCC says and has said in the past it might seem tedious to quote it at such length. But I've presented to enough undergrad classes and public audiences to know that people don't find these quotes boring, they find them incredible. If it's a question of chapter order I don't mind if there's a brief preface then the whole collection goes into the chapter appendix, but I see no benefit to omitting the material and considerable gain from including it. And I still think the best option is to lead with it.

What say others?

On Sat, May 10, 2025 at 5:55 PM Judith Curry <curry.judith@gmail.com> wrote:

See attached for my smash down of section 8.2 (13 down to 2 pages). I included on detection statements (no attribution or projections); focused on AR6 and included some statements from NCA17 and SREX that provided additional detail. I focused on summary statements from the SPM and chapter summaries (without citations of individual papers)

Let me know what you think, and whether you prefer it up front or at the end (maybe an appendix)

On Sat, May 10, 2025 at 11:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:

I like John's suggestion.

Steven E. Koonin

On May 10, 2025, at 14:36, John Christy <climateman60@gmail.com> wrote:

Judy

Would this work. Put the IPCC/NCA quotes in bold up front with a little introductory remark then add "full statements in context in appendix"?

John C.

Sent from my iPhone

On May 10, 2025, at 5:49 AM, Judith Curry <curry.judith@gmail.com> wrote:

I'm working on CH 8 Extreme Weather front end today, more soon

On Sat, May 10, 2025 at 8:37 AM Steven Koonin <steven.koonin@gmail.com> wrote:

Yes! In the exec summary and the chapter preface we must repeat something like "Contrary to popular perception..."

Steven E. Koonin

On May 10, 2025, at 11:19, Ross McKittrick
<ross.mckittrick@gmail.com> wrote:

This just appeared in the Daily Mail
<https://www.dailymail.co.uk/sciencetech/article-14686539/climate-change-affect-YOU-heatwaves-floods.html>

The extreme weather alarmism angle has been non-stop for years. People are saturated with the message that climate change = extreme weather and all scientists say it's bad and getting worse due to GHGs. It will take a lot of hammering on the theme to convince people how much they've been misled. So I don't mind if the first 15 pages of this chapter consists of mind-numbing repetition of the message that scientists don't say this and have never said it. At this point I want to hold the readers' faces in it until their limbs stop twitching and then they'll be receptive to the rest of the material.

On Fri, May 9, 2025 at 3:09 PM Judith Curry
<curry.judith@gmail.com> wrote:

I agree we should have something up front, but not pages. Will propose something more specific

On Fri, May 9, 2025 at 12:06 PM Ross McKittrick
<ross.mckittrick@gmail.com> wrote:

My read of the discussion on May 8 was that Steve made a strong pitch to move the survey back up front and you and Roy concurred. I'll let you guys debate it.

On Fri, May 9, 2025 at 3:01 PM Judith Curry
<curry.judith@gmail.com> wrote:

actually no, i thought we left this as an appendix or something (i don't think it is necessary tho). We need some sort of a summary on what the IPCC found

I have this para in the attribution chapter

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table 12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most regions in the mid-latitudes, medium confidence elsewhere
- Medium confidence in a decrease in extreme cold events in Australia, Africa and most of northern South America where observations allow trend estimation
- No evidence of emergence in the historical period of a change in river floods, heavy precipitation, drought, fire weather, severe wind storms, and tropical cyclones

On Fri, May 9, 2025 at 11:55 AM Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

I thought you said (May 8) you liked the suggestion to move them all back to the front.

On Fri, May 9, 2025 at 2:52 PM Judith Curry

<curry.judith@gmail.com> wrote:

I don't like having pages of IPCC/NCA citations (IMO the key issue is a lot of uncertainty and disagreement, and the inconsistency between chapters 11 and 12 of AR6). If we do include a shortened version of this, I would focus only on AR6, either global or US region.

On Fri, May 9, 2025 at 11:45 AM Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

In the attached Extreme Weather chapter draft I moved the IPCC/NCA excerpts back into the main

body per the discussion here and renumbered all the sections and figures mutatis mutandis. The AI summary is not bad but does need some work. Admittedly it's a lot of stuff to summarize, although the recurring theme is that trends aren't detectable and attribution to GHGs is currently not possible, in general.

On Thu, May 8, 2025 at 1:45 PM Roy Spencer

<roywspencer@hotmail.com> wrote:

This way forward is fine with me.

-Roy

From: Judith Curry <curry.judith@gmail.com>

Sent: Thursday, May 8, 2025 12:43 PM

To: John Christy <climateman60@gmail.com>

Cc: Steven Koonin <steven.koonin@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>

Subject: Re: Ch 8 Extreme weather

I think starting with IPCC up front is very useful to provide a reference point, and discussing problems with NCA motivates the unpublished data analysis

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Judith Curry
<curry.judith@gmail.com> wrote:

Ok, but the summary table (12.12 from AR6) is inconsistent with conclusions in

AR6 ch 11 (I point this out in section 6.4 of my attribution chapter).

In my mind, the main point is disagreement and ambiguity I would suggest chapter 8 going before chapter 6, retitling it as US Weather and Climate Extremes, and make it more of a data chapter, not an attribution chapter (I would put table 12.12 in the attribution chapter if you want to include the actual table)

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I like john's material too which is why I included it and am working on the extended regional analyses. But on this topic people are heavily primed to believe that extreme weather of all kinds is getting worse due to climate change.

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Judith Curry
<curry.judith@gmail.com> wrote:

I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes"

I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable severe weather event.

John's version meshes very well with my version of chapter 6. Read especially section 6.4 of my chapter. I note a discrepancy between chapters 11 and 12 in terms of detecting and attributing extreme events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the problems/challenges, and topics that are particularly relevant for the US

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added some
new Figures
showing results
on PC and SE
data and will
add the NE
chart when I get
the data. I also
made some
labeling
suggestions
including for
the 3 rainfall
charts that are
hard to
understand.
Section
summaries and
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summary are
still needed.

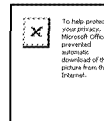
Ross

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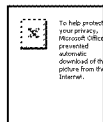
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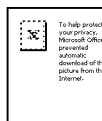
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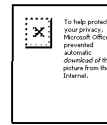


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From: Travis Fisher <travis.scott.fisher@gmail.com>
Sent: Sunday, May 11, 2025 1:23 PM
To: Judith Curry
Cc: Ross McKittrick; Steven Koonin; John Christy; Roy W. Spencer
Subject: Re: Ch 8 Extreme weather

Will do. Apologies for the rambling email... I was trying to write with a kid on my lap. Just know I'm here to help!

On Sun, May 11, 2025 at 11:53 AM Judith Curry <curry.judith@gmail.com> wrote:

Travis, your comments on readability, gaps and red flag statements would be VERY helpful. The chapters all have a complete draft, but some are still in flux

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As the non-expert member of the team, one of my contributions could be to provide input from the point of view of a reader who doesn't live and breathe these materials on a daily basis. With that in mind, I have a few observations that might help:

1) That said, I see no problem with adding more material. If the team is torn between the short version and the long version of any chapter, my preference is to leave more material and leave it to the reader whether to dig in or skim. We don't exactly have a word or page limit on this. Also, the point about cherry-picking starting points for the data is very compelling to me. It reminds me of the first time I saw the chart of air pollution data with reference to EPA's formation. Of course the trend is sharply down for criteria pollutants after 1970, but it was on a similar trend *before* 1970 as well. Those types of data-based expositions can be very powerful in refuting common misunderstandings.

2) Some of the issues you all know incredibly well could use more elaboration for the uninitiated reader, especially when you agree fully with the consensus, IPCC, or NCA view. As one example, I was looking for more info on convective events in the extreme weather chapter. I know they are covered briefly, but my reaction as the non-expert was surprise at how little focus the consensus view gives them (and how lightly that fact was discussed in your chapter). I think we should emphasize the areas where, at least according to a typical reading of the news and popular narratives, climate change is blamed for things that aren't even on an upward trend. Thunderstorms and hailstorms are certainly part of that narrative. I'm less familiar with tornadoes entering the narrative, but it was news to me that there is essentially zero correlation with temperatures, and that type of information could be news to the typical reader as well. In other words, you could emphasize the areas where you all agree with IPCC/NCA/etc, which in turn would help anchor this report to the consensus view. That borders on a political or public affairs consideration, I know, so please feel free to ignore it completely.

3) I can see why the Secretary chose this team. You all are world-class experts. It's been a privilege to watch this report come together, and I'll do everything in my power to make it something you all can be proud of. If you want me to add comment bubbles to flag areas where the non-expert might trip up, I'd be happy to do that. Or if there's anything else I can do aside from the next glossary and the cover letter from the Secretary (and coordination with EPA), please let me know.

4) I took too long to hit send on this email, and I see a new one from Judy. +1 to Judy's point about leaving evaluations and judgments out of the body of the report. I may also try to flag areas where I see opinions or

the inevitable pejorative. Personally, I had no idea how slick some of the NCA findings were in terms of narrowly defining the state of the climate to generate the appearance of a crisis, and I have become a new level of cynical after seeing it more clearly, thanks to you all. I'm excited to see the much-needed conversations this report will generate.

Best,
Travis

On Sun, May 11, 2025 at 11:06 AM Judith Curry <curry.judith@gmail.com> wrote:

Well the point of JC and RS analyses later in the chapter demonstrate the importance of looking back prior to 1950. And i think we should stick to conclusion statements in the SPM and Chapter summaries, rather than the text of the report that cites primary references (that looks like cherry picking). And AR6 is the main doc driving policy arguments; i don't think EPA lawyers are going to go back to AR5

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My concerns are that these excerpts leave out too much valuable material and that they lead with the AR6 cherry-picked 1950s as the starting point for trends. Both with respect to heatwaves and precip the only way to detect increases is to compare back to the 50s. If they include the 1930s or further back the heatwave picture falls apart, and as we show further in the chapter the precip picture falls apart either starting in the 70s or the 1800s. This selection puts us in a weak position where we will appear to be arguing against IPCC assessments using our own data, even though the more complete survey shows that our data aligns with what the assessments have been saying all along.

One reason to include material from the past assessment reports is that people have been hearing a narrative about extreme weather for 20+ years. A brief survey won't suffice to overcome the cognitive dissonance we're up against in this chapter. The comprehensive survey of IPCC and NCA material is the only way to overcome it. If we only show the AR6 they might think that's somehow new whereas prior reports said something else. I want to show convincingly that the message today is about the same as it's always been.

For those of us who know what the IPCC says and has said in the past it might seem tedious to quote it at such length. But I've presented to enough undergrad classes and public audiences to know that people don't find these quotes boring, they find them incredible. If it's a question of chapter order I don't mind if there's a brief preface then the whole collection goes into the chapter appendix, but I see no benefit to omitting the material and considerable gain from including it. And I still think the best option is to lead with it.

What say others?

On Sat, May 10, 2025 at 5:55 PM Judith Curry <curry.judith@gmail.com> wrote:

See attached for my smash down of section 8.2 (13 down to 2 pages). I included on detection statements (no attribution or projections); focused on AR6 and included some statements from NCA17 and SREX that provided additional detail. I focused on summary statements from the SPM and chapter summaries (without citations of individual papers)

Let me know what you think, and whether you prefer it up front or at the end (maybe an appendix)

On Sat, May 10, 2025 at 11:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:

I like John's suggestion.

Steven E. Koonin

On May 10, 2025, at 14:36, John Christy <climateman60@gmail.com> wrote:

Judy

Would this work. Put the IPCC/NCA quotes in bold up front with a little introductory remark then add “full statements in context in appendix”?

John C.

Sent from my iPhone

On May 10, 2025, at 5:49 AM, Judith Curry <curry.judith@gmail.com> wrote:

I'm working on CH 8 Extreme Weather front end today, more soon

On Sat, May 10, 2025 at 8:37 AM Steven Koonin
<steven.koonin@gmail.com> wrote:

Yes! In the exec summary and the chapter preface we must repeat something like “Contrary to popular perception...”

Steven E. Koonin

On May 10, 2025, at 11:19, Ross McKittrick
<ross.mckittrick@gmail.com> wrote:

This just appeared in the Daily Mail
<https://www.dailymail.co.uk/sciencetech/article-14686539/climate-change-affect-YOU-heatwaves-floods.html>

The extreme weather alarmism angle has been non-stop for years. People are saturated with the message that climate change = extreme weather and all scientists say it's bad and getting worse due to GHGs. It will take a lot of hammering on the theme to convince people how much they've been misled. So I don't mind if the first 15 pages of this chapter consists of mind-numbing repetition of the message that scientists don't say this and have never said it. At this point I want to hold the readers' faces in it until their limbs stop

twitching and then they'll be receptive to the rest of the material.

On Fri, May 9, 2025 at 3:09 PM Judith Curry

<curry.judith@gmail.com> wrote:

I agree we should have something up front, but not pages. Will propose something more specific

On Fri, May 9, 2025 at 12:06 PM Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

My read of the discussion on May 8 was that Steve made a strong pitch to move the survey back up front and you and Roy concurred. I'll let you guys debate it.

On Fri, May 9, 2025 at 3:01 PM Judith Curry

<curry.judith@gmail.com> wrote:

actually no, i thought we left this as an appendix or something (i don't think it is necessary tho). We need some sort of a summary on what the IPCC found

I have this para in the attribution chapter

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table 12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most regions in the mid-latitudes, medium confidence elsewhere
- Medium confidence in a decrease in extreme cold events in Australia, Africa and most of northern South America where observations allow trend estimation
- No evidence of emergence in the historical period of a change in river floods, heavy precipitation, drought, fire weather, severe wind storms, and tropical cyclones

On Fri, May 9, 2025 at 11:55 AM Ross McKitrick

<ross.mckitrick@gmail.com> wrote:

I thought you said (May 8) you liked the suggestion to move them all back to the front.

On Fri, May 9, 2025 at 2:52 PM Judith Curry

<curry.judith@gmail.com> wrote:

I don't like having pages of IPCC/NCA citations (IMO the key issue is a lot of uncertainty and disagreement, and the inconsistency between chapters 11 and 12 of AR6). If we do include a shortened version of this, i would focus only on AR6, either global or US region.

On Fri, May 9, 2025 at 11:45 AM Ross McKitrick

<ross.mckitrick@gmail.com> wrote:

In the attached Extreme Weather chapter draft I moved the IPCC/NCA excerpts back into the main body per the discussion here and renumbered all the sections and figures mutatis mutandis.

The AI summary is not bad but does need some work. Admittedly it's a lot of stuff to summarize, although the recurring theme is that trends aren't detectable and attribution to GHGs is currently not possible, in general.

On Thu, May 8, 2025 at 1:45 PM Roy Spencer

<roywspencer@hotmail.com> wrote:

This way forward is fine with me.

-Roy

From: Judith Curry <curry.judith@gmail.com>

Sent: Thursday, May 8, 2025 12:43 PM

To: John Christy <climateman60@gmail.com>

Cc: Steven Koonin <steven.koonin@gmail.com>; Ross McKitrick <ross.mckitrick@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher

<travis.scott.fisher@gmail.com>

Subject: Re: Ch 8 Extreme weather

I think starting with IPCC up front is very useful to provide a reference point, and discussing problems with NCA motivates the unpublished data analysis

On Thu, May 8, 2025 at 10:36 AM John Christy

<climateman60@gmail.com> wrote:

Ultimately the order will likely not matter. We are somewhat conflicted. On one hand we show the Assessments are consistent with our conclusions about extreme weather, but on the other hand we find them (especially NCAs) deceptive in presenting the information that skews their results to lean toward alarmism. This is true of other chapters as well.

At the least we should mention this nuance perhaps up front.

John C.

Sent from my iPhone

On May 8, 2025, at 6:23 AM, Judith Curry <curry.judith@gmail.com> wrote:

I also agree with this organization, was thinking the same thing

On Thu, May 8, 2025 at 8:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:

Attached are my comments/edits on Chapter 8.

I'd like to make a strong pitch to reorder the text so that the survey of previous assessments comes first, then followed by the new work from John and Ross. There are several reasons for this that I can elaborate, but the most important is that the official assessments already make the case and,

no offense guys, carry far more authority in the non-expert world.

SEK

PS Note for interest and amusement the AI-generated summary section.

From: Ross McKittrick
<ross.mckittrick@gmail.com>
Sent: Tuesday, May 6, 2025 1:05 PM
To: John Christy
<climateman60@gmail.com>
Cc: Judith Curry
<curry.judith@gmail.com>; Roy W. Spencer
<roywspencer@hotmail.com>; Travis Fisher
<travis.scott.fisher@gmail.com>;
Steven Koonin
<steven.koonin@gmail.com>
Subject: Re: Ch 8 Extreme weather

Here's another edition of Ch 8 on extremes taking Judy's and John's points into account. The IPCC/NCA review is ported to an Appendix. I added a paragraph about LTP to the intro. I've incorporated the NE data. The bulk of the chapter is John's US temperature and precip data analysis with some additional material on wildfires, drought and TCs. For the US temperature extremes I moved the range figure to come just after the hot/cold extremes count because I think they both make a coherent point namely that the US becoming less extreme because heat events are rising more slowly than cold events are warming. There will still need to be an overall chapter summary but I'm

going to move on to other chapters now. I'll put this in the Dropbox.

On Tue, May 6, 2025 at 12:12 PM
John Christy
<climateman60@gmail.com>
wrote:

All

We can fill in without much trouble the change, or lack thereof, of “high impact” weather events (mainly wind and flooding like hurricanes, tornadoes etc) in the CONUS Extreme chapter. The temp and precip metrics are important because they are just long enough to essentially tell us Mother Nature has a mind of her own.

1. I'll look at Ross's version of 8 soon, but my hope was that Ross would translate the statistical remarks into the correct language(eg are their more precise words that chaotic, episodic, stochastic, etc).

2. We have analyses of the CONUS with more complete datasets than the NCA used (recall NCA analyses depended essentially on a small group at NCEI using datasets that (a) were not very consistent in time, (b) could promote alarm and (c) already easy for them to get to. Our datasets have literally hundreds of thousands of manually

keyed-in observations for temporal consistency. In other words, this lets people know we can address these issues from soup to nuts - we're not armchair climate scientists ... we can reproduce what they did, but make the analysis more comprehensive to address the questions.

John C.

Sent from my iPhone

On May 6, 2025, at
4:14 AM, Ross
McKittrick

<ross.mckittrick@gmail.com> wrote:

Just read your attribution chapter. I hadn't picked up on the gap between IPCC Ch 11 vs Ch 12 language but i see your point that rather than promoting one set of attribution findings we should explain that even within the same AR different authors assessed things differently. One option is to leave Ch 6 where it is but

reverse the order of Ch 7 and 8 while retitling the latter as you suggest. That way, having established the extreme weather types for which there are no detectable trends it will more naturally follow that they won't be discussed in the attribution chapter.

On Tue, May 6,
2025 at 9:45 AM
Judith Curry
<curry.judith@gmail.com> wrote:

Ok, but the summary table (12.12 from AR6) is inconsistent with conclusions in AR6 ch 11 (I point this out in section 6.4 of my attribution chapter).

In my mind, the main point is disagreement and ambiguity I would suggest chapter 8 going before chapter 6, retitling it as US Weather and Climate Extremes, and make it more of a data chapter, not

an attribution
chapter (I would
put table 12.12 in
the attribution
chapter if you want
to include the
actual table)

On Tue, May 6,
2025 at 6:39 AM
Ross McKittrick
<ross.mckittrick@gmail.com> wrote:

I like john's
material too
which is why I
included it and
am working
on the extended
regional analyses.
But on this topic
people are heavily
primed to believe
that extreme
weather of all
kinds is getting
worse due to
climate change.
The assertion
shows up
everywhere
climate change is
discussed
including in
academic papers.
I think it is very
valuable to show
people that
neither the IPCC
nor the NCA
support such this
view. We should
at least lead off
with the summary
table. The library
of quotes can go
to an appendix
but I have found

in my public speaking that they have considerable persuasive force for most people. We also need to address floods, droughts, hurricane landfalls, tornadoes etc. I don't see any reason to delete all that material.

On Tue, May 6, 2025 at 9:22 AM Judith Curry <curry.judith@gmail.com> wrote:

I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes"

I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable severe weather event.

John's version meshes very well with my version of chapter 6. Read especially

section 6.4 of my chapter. I note a discrepancy between chapters 11 and 12 in terms of detecting and attributing extreme events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the problems/challenges, and topics that are particularly relevant for the US

On Mon, May 5,
2025 at 7:47 PM
Ross McKitrick
<ross.mckitrick@gmail.com>
wrote:

I have wrangled the extreme weather chapter into something I hope flows better and is more readable. I adopted Judy's editorial changes and then the new changes I made are in red. I added some

new Figures
showing results
on PC and SE
data and will
add the NE
chart when I get
the data. I also
made some
labeling
suggestions
including for
the 3 rainfall
charts that are
hard to
understand.
Section
summaries and
an overall
summary are
still needed.

Ross

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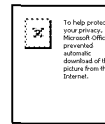
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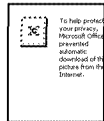
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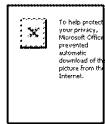
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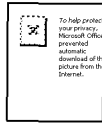
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Best,
Travis

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One reason to include material from the past assessment reports is that people have been hearing a narrative about extreme weather for 20+ years. A brief survey won't suffice to overcome the cognitive dissonance we're up against in this chapter. The comprehensive survey of IPCC and NCA material is the only way to overcome it. If we only show the AR6 they might think that's somehow new whereas prior reports said something else. I want to show convincingly that the message today is about the same as it's always been.

For those of us who know what the IPCC says and has said in the past it might seem tedious to quote it at such length. But I've presented to enough undergrad classes and public audiences to know that people don't find these quotes boring, they find them incredible. If it's a question of chapter order I don't mind if there's a brief preface then the whole collection goes into the chapter appendix, but I see no benefit to omitting the material and considerable gain from including it. And I still think the best option is to lead with it.

What say others?

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See attached for my smash down of section 8.2 (13 down to 2 pages). I included on detection statements (no attribution or projections); focused on AR6 and included some statements from NCA17 and SREX that provided additional detail. I focused on summary statements from the SPM and chapter summaries (without citations of individual papers)

Let me know what you think, and whether you prefer it up front or at the end (maybe an appendix)

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I like John's suggestion.

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Would this work. Put the IPCC/NCA quotes in bold up front with a little introductory remark then add “full statements in context in appendix”?

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My read of the discussion on May 8 was that Steve made a strong pitch to move the survey back up front and you and Roy concurred. I'll let you guys debate it.

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actually no, i thought we left this as an appendix or something (i don't think it is necessary tho). We need some sort of a summary on what the IPCC found

I have this para in the attribution chapter

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table 12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most regions in the mid-latitudes, medium confidence elsewhere
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I don't like having pages of IPCC/NCA citations (IMO the key issue is a lot of uncertainty and disagreement, and the inconsistency between chapters 11 and 12 of AR6). If we do include a shortened version of this, i would focus only on AR6, either global or US region.

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In the attached Extreme Weather chapter draft I moved the IPCC/NCA excerpts back into the main body per the discussion here and renumbered all the sections and figures mutatis mutandis.

The AI summary is not bad but does need some work. Admittedly it's a lot of stuff to summarize, although the recurring theme is that trends aren't detectable and attribution to GHGs is currently not possible, in general.

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Cc: Steven Koonin <steven.koonin@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>

Subject: Re: Ch 8 Extreme weather

I think starting with IPCC up front is very useful to provide a reference point, and discussing problems with NCA motivates the unpublished data analysis

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Ultimately the order will likely not matter. We are somewhat conflicted. On one hand we show the Assessments are consistent with our conclusions about extreme weather, but on the other hand we find them (especially NCAs) deceptive in presenting the information that skews their results to lean toward alarmism. This is true of other chapters as well.

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Attached are my comments/edits on Chapter 8.

I'd like to make a strong pitch to reorder the text so that the survey of previous assessments comes first, then followed by the new work from John and Ross. There are several reasons for this that I can elaborate, but the most important is that the official assessments already make the case and, no offense guys, carry far more authority in the non-expert world.

SEK

PS Note for interest and amusement the
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Travis Fisher
<travis.scott.fisher@gmail.com>;
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Here's another edition of Ch 8 on extremes taking Judy's and John's points into account. The IPCC/NCA review is ported to an Appendix. I added a paragraph about LTP to the intro. I've incorporated the NE data. The bulk of the chapter is John's US temperature and precip data analysis with some additional material on wildfires, drought and TCs. For the US temperature extremes I moved the range figure to come just after the hot/cold extremes count because I think they both make a coherent point namely that the US becoming less extreme because heat events are rising more slowly than cold events are warming. There will still need to be an overall chapter summary but I'm going to move on to other chapters now. I'll put this in the Dropbox.

On Tue, May 6, 2025 at 12:12 PM
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We can fill in without much trouble the change, or lack thereof, of “high impact” weather events (mainly wind and flooding like hurricanes, tornadoes etc) in the CONUS Extreme chapter. The temp and precip metrics are important because they are just long enough to essentially tell us Mother Nature has a mind of her own.

1. I’ll look at Ross’s version of 8 soon, but my hope was that Ross would translate the statistical remarks into the correct language(eg are their more precise words that chaotic, episodic, stochastic, etc).

2. We have analyses of the CONUS with more complete datasets than the NCA used (recall NCA analyses depended essentially on a small group at NCEI using datasets that (a) were not very consistent in time, (b) could promote alarm and (c) already easy for them to get to. Our datasets have literally hundreds of thousands of manually keyed-in observations for temporal consistency. In other words, this lets people know we can address these issues from soup to nuts - we’re not armchair climate scientists ... we can reproduce what they did, but make the analysis more comprehensive to address the questions.

John C.

Sent from my iPhone

On May 6, 2025, at
4:14 AM, Ross
McKittrick

[<ross.mckittrick@gmail.com>](mailto:ross.mckittrick@gmail.com) wrote:

Just read your attribution chapter. I hadn't picked up on the gap between IPCC Ch 11 vs Ch 12 language but i see your point that rather than promoting one set of attribution findings we should explain that even within the same AR different authors assessed things differently. One option is to leave Ch 6 where it is but reverse the order of Ch 7 and 8 while retitling the latter as you suggest. That way, having established the extreme weather types for which there are no detectable trends it will more naturally follow that they won't be discussed in the attribution chapter.

On Tue, May 6,
2025 at 9:45 AM
Judith Curry
<curry.judith@gmail.com> wrote:

Ok, but the
summary table
(12.12 from AR6) is
inconsistent with
conclusions in AR6
ch 11 (I point this
out in section 6.4 of
my attribution
chapter).

In my mind, the
main point is
disagreement and
ambiguity I would
suggest chapter 8
going before
chapter 6, retitling it
as US Weather and
Climate Extremes,
and make it more of
a data chapter, not
an attribution
chapter (I would
put table 12.12 in
the attribution
chapter if you want
to include the actual
table)

On Tue, May 6,
2025 at 6:39 AM
Ross McKittrick
<ross.mckittrick@gmail.com> wrote:

I like john's
material too which

is why I included it
and am working
on the extended
regional analyses.
But on this topic
people are heavily
primed to believe
that extreme
weather of all
kinds is getting
worse due to
climate change.
The assertion
shows up
everywhere
climate change is
discussed
including in
academic papers. I
think it is very
valuable to show
people that neither
the IPCC nor the
NCA support such
this view. We
should at least lead
off with the
summary table.
The library of
quotes can go to an
appendix but I
have found in my
public speaking
that they have
considerable
persuasive force
for most people.
We also need to
address floods,
droughts, hurricane
landfalls,
tornadoes etc. I
don't see any
reason to delete all
that material.

On Tue, May 6,
2025 at 9:22 AM
Judith Curry

<curry.judith@gmail.com> wrote:

I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes"

I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable severe weather event.

John's version meshes very well with my version of chapter 6. Read especially section 6.4 of my chapter. I note a discrepancy between chapters 11 and 12 in terms of detecting and attributing extreme events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the problems/challenges, and topics that are particularly relevant for the US

On Mon, May 5,
2025 at 7:47 PM
Ross McKittrick
<ross.mckittrick@gmail.com>
wrote:

I have wrangled
the extreme
weather chapter
into something I
hope flows better
and is more
readable. I
adopted Judy's
editorial
changes and then
the new changes
I made are in
red. I added
some new
Figures
showing results
on PC and SE
data and will add
the NE chart
when I get the
data. I also made
some labeling
suggestions
including for the
3 rainfall charts
that are hard to
understand.
Section
summaries and
an overall
summary are still
needed.

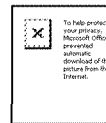
Ross

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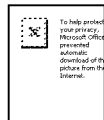
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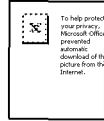


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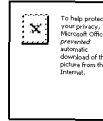


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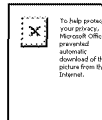
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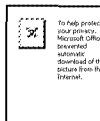
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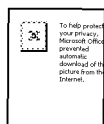
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Sent: Sunday, May 11, 2025 11:06 AM
To: Ross McKittrick
Cc: Steven Koonin; John Christy; Roy W. Spencer; Travis Fisher
Subject: Re: Ch 8 Extreme weather

Well the point of JC and RS analyses later in the chapter demonstrate the importance of looking back prior to 1950. And i think we should stick to conclusion statements in the SPM and Chapter summaries, rather than the text of the report that cites primary references (that looks like cherry picking). And AR6 is the main doc driving policy arguments; i don't think EPA lawyers are going to go back to AR5

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John C.

Sent from my iPhone

On May 6, 2025, at
4:14 AM, Ross
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<ross.mckittrick@gmail.com> wrote:

Just read your attribution chapter. I hadn't picked up on the gap between IPCC Ch 11 vs Ch 12 language but i see your point that rather than promoting one set of attribution findings we should explain that even within the same AR different authors assessed things differently. One option is to leave Ch 6 where it is but reverse the order of Ch 7 and 8 while retitling the latter as you suggest. That way, having established the extreme weather types for which there are no detectable trends it will more naturally follow that they won't be discussed in the attribution chapter.

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Curry
<curry.judith@gmail.com> wrote:

Ok, but the summary table (12.12 from AR6) is inconsistent with conclusions in AR6 ch 11 (I point this out in section 6.4 of my attribution chapter).

In my mind, the main point is disagreement and ambiguity I would suggest chapter 8 going before chapter 6, retitling it as US Weather and Climate Extremes, and make it more of a data chapter, not an attribution chapter (I would put table 12.12 in the attribution chapter if you want to include the actual table)

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Judith Curry
<curry.judith@gmail.com> wrote:

I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes"

I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable severe weather event.

John's version meshes very well with my version of chapter 6. Read especially section 6.4 of my chapter. I note a discrepancy between chapters 11 and 12 in terms of detecting and attributing extreme events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the problems/challenges, and topics that are particularly relevant for the US

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Ross McKittrick
<ross.mckitrick@gmail.com> wrote:

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get the data. I also
made some
labeling
suggestions
including for the 3
rainfall charts that
are hard to
understand.
Section summaries
and an overall
summary are still
needed.

Ross

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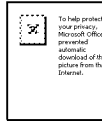
Judith Curry, President
CFAN - Climate Forecast Applications Network
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curry.judith@cfanclimate.com | +1.404.803.201
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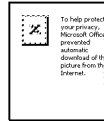
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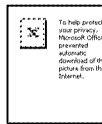
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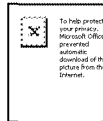
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From: Ross McKittrick <ross.mckitrick@gmail.com>
Sent: Sunday, May 11, 2025 10:39 AM
To: Judith Curry
Cc: Steven Koonin; John Christy; Roy W. Spencer; Travis Fisher
Subject: Re: Ch 8 Extreme weather

My concerns are that these excerpts leave out too much valuable material and that they lead with the AR6 cherry-picked 1950s as the starting point for trends. Both with respect to heatwaves and precip the only way to detect increases is to compare back to the 50s. If they include the 1930s or further back the heatwave picture falls apart, and as we show further in the chapter the precip picture falls apart either starting in the 70s or the 1800s. This selection puts us in a weak position where we will appear to be arguing against IPCC assessments using our own data, even though the more complete survey shows that our data aligns with what the assessments have been saying all along.

One reason to include material from the past assessment reports is that people have been hearing a narrative about extreme weather for 20+ years. A brief survey won't suffice to overcome the cognitive dissonance we're up against in this chapter. The comprehensive survey of IPCC and NCA material is the only way to overcome it. If we only show the AR6 they might think that's somehow new whereas prior reports said something else. I want to show convincingly that the message today is about the same as it's always been.

For those of us who know what the IPCC says and has said in the past it might seem tedious to quote it at such length. But I've presented to enough undergrad classes and public audiences to know that people don't find these quotes boring, they find them incredible. If it's a question of chapter order I don't mind if there's a brief preface then the whole collection goes into the chapter appendix, but I see no benefit to omitting the material and considerable gain from including it. And I still think the best option is to lead with it.

What say others?

On Sat, May 10, 2025 at 5:55 PM Judith Curry <curry.judith@gmail.com> wrote:

See attached for my smash down of section 8.2 (13 down to 2 pages). I included on detection statements (no attribution or projections); focused on AR6 and included some statements from NCA17 and SREX that provided additional detail. I focused on summary statements from the SPM and chapter summaries (without citations of individual papers)

Let me know what you think, and whether you prefer it up front or at the end (maybe an appendix)

On Sat, May 10, 2025 at 11:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:

I like John's suggestion.

Steven E. Koonin

On May 10, 2025, at 14:36, John Christy <climateman60@gmail.com> wrote:

Judy

Would this work. Put the IPCC/NCA quotes in bold up front with a little introductory remark then add “full statements in context in appendix”?

John C.

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This just appeared in the Daily Mail
<https://www.dailymail.co.uk/sciencetech/article-14686539/climate-change-affect-YOU-heatwaves-floods.html>

The extreme weather alarmism angle has been non-stop for years. People are saturated with the message that climate change = extreme weather and all scientists say it's bad and getting worse due to GHGs. It will take a lot of hammering on the theme to convince people how much they've been misled. So I don't mind if the first 15 pages of this chapter consists of mind-numbing repetition of the message that scientists don't say this and have never said it. At this point I want to hold the readers' faces in it until their limbs stop twitching and then they'll be receptive to the rest of the material.

On Fri, May 9, 2025 at 3:09 PM Judith Curry
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I agree we should have something up front, but not pages. Will propose something more specific

On Fri, May 9, 2025 at 12:06 PM Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

My read of the discussion on May 8 was that Steve made a strong pitch to move the survey back up front and you and Roy concurred. I'll let you guys debate it.

On Fri, May 9, 2025 at 3:01 PM Judith Curry

<curry.judith@gmail.com> wrote:

actually no, i thought we left this as an appendix or something (i don't think it is necessary tho). We need some sort of a summary on what the IPCC found

I have this para in the attribution chapter

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table 12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most regions in the mid-latitudes, medium confidence elsewhere
- Medium confidence in a decrease in extreme cold events in Australia, Africa and most of northern South America where observations allow trend estimation
- No evidence of emergence in the historical period of a change in river floods, heavy precipitation, drought, fire weather, severe wind storms, and tropical cyclones

On Fri, May 9, 2025 at 11:55 AM Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

I thought you said (May 8) you liked the suggestion to move them all back to the front.

On Fri, May 9, 2025 at 2:52 PM Judith Curry

<curry.judith@gmail.com> wrote:

I don't like having pages of IPCC/NCA citations (IMO the key issue is a lot of uncertainty and disagreement, and the inconsistency between chapters 11 and 12 of AR6). If we do include a shortened version of this, i would focus only on AR6, either global or US region.

On Fri, May 9, 2025 at 11:45 AM Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

In the attached Extreme Weather chapter draft I moved the IPCC/NCA excerpts back into the main body per the discussion here and renumbered all the sections and figures mutatis mutandis.

The AI summary is not bad but does need some work. Admittedly it's a lot of stuff to summarize, although the recurring theme is that trends aren't detectable and attribution to GHGs is currently not possible, in general.

On Thu, May 8, 2025 at 1:45 PM Roy Spencer

<roywspencer@hotmail.com> wrote:

This way forward is fine with me.

-Roy

From: Judith Curry <curry.judith@gmail.com>

Sent: Thursday, May 8, 2025 12:43 PM

To: John Christy <climateman60@gmail.com>

Cc: Steven Koonin <steven.koonin@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Roy W. Spencer

<roywspencer@hotmail.com>; Travis Fisher

<travis.scott.fisher@gmail.com>

Subject: Re: Ch 8 Extreme weather

I think starting with IPCC up front is very useful to provide a reference point, and discussing problems with NCA motivates the unpublished data analysis

On Thu, May 8, 2025 at 10:36 AM John Christy

<climateman60@gmail.com> wrote:

Ultimately the order will likely not matter. We are somewhat conflicted. On one hand we show the Assessments are consistent with our conclusions about extreme weather, but on the other hand we find them (especially NCAs) deceptive in presenting the

information that skews their results to lean toward alarmism. This is true of other chapters as well.

At the least we should mention this nuance perhaps up front.

John C.

Sent from my iPhone

On May 8, 2025, at 6:23 AM, Judith Curry <curry.judith@gmail.com> wrote:

I also agree with this organization, was thinking the same thing

On Thu, May 8, 2025 at 8:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:

Attached are my comments/edits on Chapter 8.

I'd like to make a strong pitch to reorder the text so that the survey of previous assessments comes first, then followed by the new work from John and Ross. There are several reasons for this that I can elaborate, but the most important is that the official assessments already make the case and, no offense guys, carry far more authority in the non-expert world.

SEK

PS Note for interest and amusement the AI-generated summary section.

From: Ross McKittrick
<ross.mckittrick@gmail.com>
Sent: Tuesday, May 6, 2025 1:05 PM
To: John Christy

<climateman60@gmail.com>
Cc: Judith Curry <curry.judith@gmail.com>;
Roy W. Spencer
<roywspencer@hotmail.com>; Travis
Fisher <travis.scott.fisher@gmail.com>;
Steven Koonin
<steven.koonin@googlemail.com>
Subject: Re: Ch 8 Extreme weather

Here's another edition of Ch 8 on extremes taking Judy's and John's points into account. The IPCC/NCA review is ported to an Appendix. I added a paragraph about LTP to the intro. I've incorporated the NE data. The bulk of the chapter is John's US temperature and precip data analysis with some additional material on wildfires, drought and TCs. For the US temperature extremes I moved the range figure to come just after the hot/cold extremes count because I think they both make a coherent point namely that the US becoming less extreme because heat events are rising more slowly than cold events are warming. There will still need to be an overall chapter summary but I'm going to move on to other chapters now. I'll put this in the Dropbox.

On Tue, May 6, 2025 at 12:12 PM John Christy <climateman60@gmail.com> wrote:

All

We can fill in without much trouble the change, or lack thereof, of “high impact” weather events (mainly wind and flooding like hurricanes, tornadoes etc) in the CONUS Extreme chapter. The temp and precip metrics are

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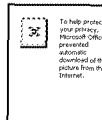
Ross

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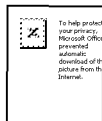
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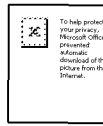
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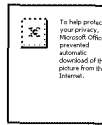
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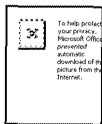
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From: John Christy [climateman60@gmail.com]
Sent: 5/11/2025 3:20:08 AM
To: Judith Curry [curry.judith@gmail.com]
CC: Steve Koonin [steven.koonin@gmail.com]; Ross McKittrick [ross.mckittrick@gmail.com]; Roy W. Spencer [roywspencer@hotmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]
Subject: Re: Ch 8 Extreme weather

I like Judy's "preamble" as it preconditions the reader to think in less alarming terms without overwhelming them with IPCC-ish word volume. I still think we need the direct words Steve mentioned regarding the incorrect public perception that weather is becoming more extreme and frequent ... perhaps in the line above Judy's 8.2.1.

Ross: I tried to snip chapter 8 from the whole document file, but of course, the numbering system went crazy. So here are a couple of edits I'll leave you to add.

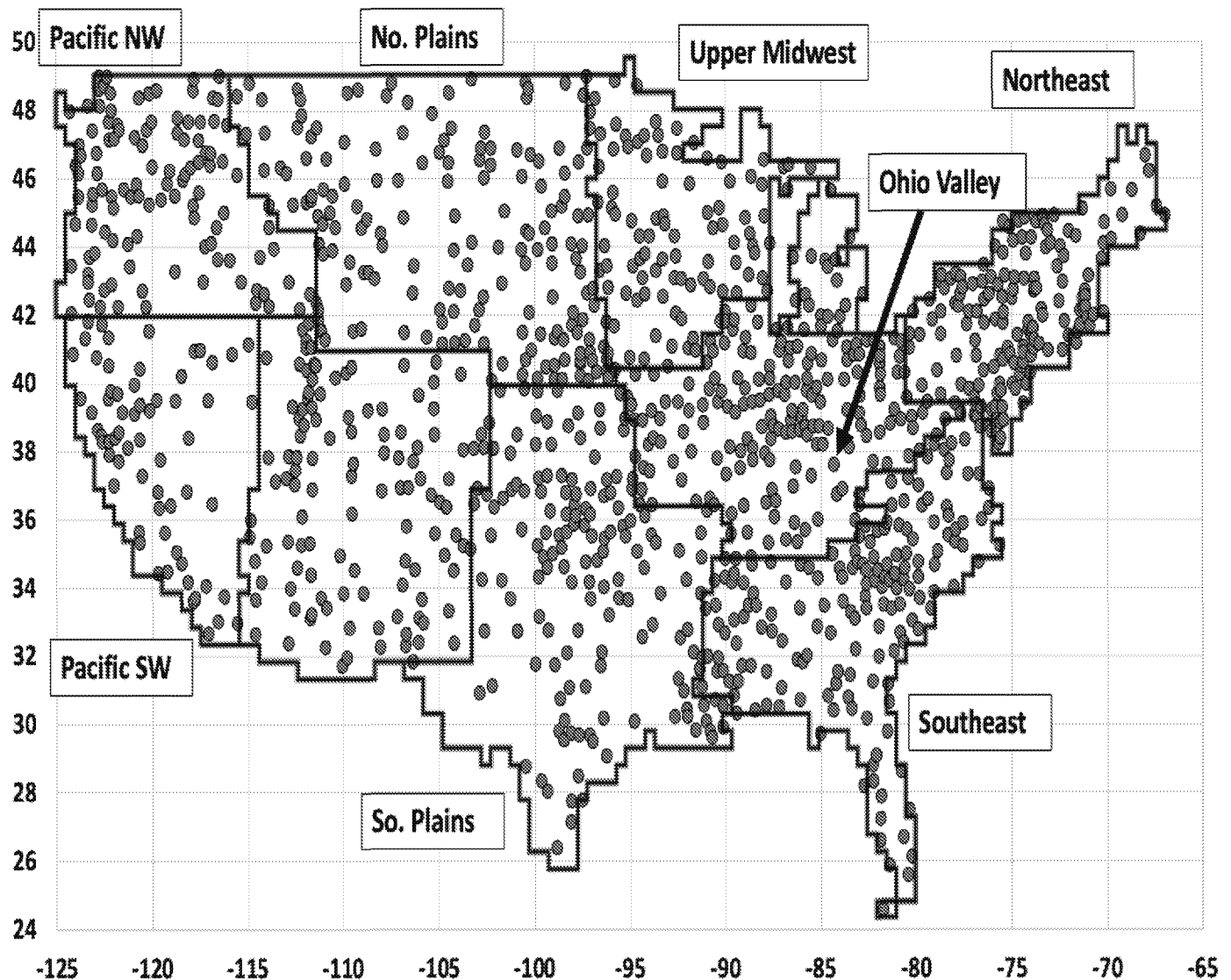
Map of 1,211 stations with regions attached for section 8.4.

Sidebar. Annual dates indicate the water-year in which the record occurred. The W-Y for the Pacific Coast used here is August to July. Thus the "2023" records were sometimes in Dec 2022 (but crossed the calendar year for the longer periods into 2023). So, something like this can be added, "Dates represent the ending year of the water-year in which the event occurred, i.e. 2023 indicates the event occurred between Aug 2022 and July 2023.)"

Steve - the values were interpolated to a 0.5 degree grid and then geographically (i.e. cosine latitude) weighted. Thus varying density is removed as an influencing factor. I was not comfortable in interpolating beyond 125 km, so parts of west TX, NV and CA have a few spatial gaps. Overall, the area of the CONUS represented with non-missing values is 99%.

John C.

John Christy
Director, Earth System Science Center
Professor, Atmos and Earth Science
Alabama State Climatologist
The University of Alabama in Huntsville
climateman60@gmail.com



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Sent: Thursday, May 8, 2025 12:43 PM

To: John Christy <climateman60@gmail.com>

Cc: Steven Koonin <steven.koonin@gmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>

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with some additional material on wildfires, drought and TCs. For the US temperature extremes I moved the range figure to come just after the hot/cold extremes count because I think they both make a coherent point namely that the US becoming less extreme because heat events are rising more slowly than cold events are warming. There will still need to be an overall chapter summary but I'm going to move on to other chapters now. I'll put this in the Dropbox.

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On Tue, May 6, 2025 at 9:45 AM Judith Curry <curry.judith@gmail.com> wrote:

Ok, but the summary table (12.12 from AR6) is inconsistent with conclusions in AR6 ch 11 (I point this out in section 6.4 of my attribution chapter).

In my mind, the main point is disagreement and ambiguity I would suggest chapter 8 going before chapter 6, retitling it as US Weather and Climate Extremes, and make it more of a data chapter, not an attribution chapter (I would put table 12.12 in the attribution chapter if you want to include the actual table)

On Tue, May 6, 2025 at 6:39 AM Ross McKittrick <ross.mckitrick@gmail.com> wrote:

I like John's material too which is why I included it and am working on the extended regional analyses. But on this topic people are heavily primed to believe that extreme weather of all kinds is getting worse due to climate change. The assertion shows up everywhere climate change is discussed including in academic papers. I think it is very valuable to show people that neither the IPCC nor the NCA support such this view. We should at least lead off with the summary table. The library of quotes can go to an appendix but I have found in my public speaking that they have considerable persuasive force for most people. We also need to address floods, droughts, hurricane landfalls, tornadoes etc. I don't see any reason to delete all that material.

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I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes" I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable severe weather event.

John's version meshes very well with my version of chapter 6. Read especially section 6.4 of my chapter. I note a discrepancy between chapters 11 and 12 in terms of detecting and attributing extreme events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the problems/challenges, and topics that are particularly relevant for the US

On Mon, May 5, 2025 at 7:47 PM Ross McKittrick <ross.mckitrick@gmail.com> wrote:

I have wrangled the extreme weather chapter into something I hope flows better and is more readable. I adopted Judy's editorial changes and then the new changes I made are in red. I added some new Figures showing results on PC and SE data and will add the NE chart when I get the data. I also made some labeling suggestions including for the 3 rainfall charts that are hard to understand. Section summaries and an overall summary are still needed.

Ross

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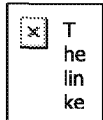
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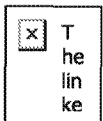
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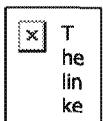
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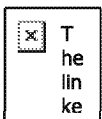
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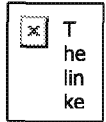
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<ch 8 preamble.docx>

From: Judith Curry <curry.judith@gmail.com>
Sent: Saturday, May 10, 2025 7:45 PM
To: Steven Koonin
Cc: John Christy; Ross McKittrick; Roy W. Spencer; Travis Fisher
Subject: Re: Ch 8 Extreme weather

Uh oh, read this see towards end re NSF

<https://balancedweather.substack.com/p/balancedwx-special-unidata-suspends>

On Sat, May 10, 2025 at 11:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:
I like John's suggestion.

Steven E. Koonin

On May 10, 2025, at 14:36, John Christy <climateman60@gmail.com> wrote:

Judy

Would this work. Put the IPCC/NCA quotes in bold up front with a little introductory remark then add "full statements in context in appendix"?

John C.

Sent from my iPhone

On May 10, 2025, at 5:49 AM, Judith Curry <curry.judith@gmail.com> wrote:

I'm working on CH 8 Extreme Weather front end today, more soon

On Sat, May 10, 2025 at 8:37 AM Steven Koonin <steven.koonin@gmail.com> wrote:

Yes! In the exec summary and the chapter preface we must repeat something like "Contrary to popular perception..."

Steven E. Koonin

On May 10, 2025, at 11:19, Ross McKittrick
<ross.mckittrick@gmail.com> wrote:

This just appeared in the Daily Mail
<https://www.dailymail.co.uk/sciencetech/article-14686539/climate-change-affect-YOU-heatwaves-floods.html>

The extreme weather alarmism angle has been non-stop for years. People are saturated with the message that climate change = extreme weather and all scientists say it's bad and getting worse due to GHGs. It will take a lot of hammering on the theme to convince people how much they've been misled. So I don't mind if the first 15 pages of this chapter consists of mind-numbing repetition of the message that scientists don't say this and have never said it. At this point I want to hold the readers' faces in it until their limbs stop twitching and then they'll be receptive to the rest of the material.

On Fri, May 9, 2025 at 3:09 PM Judith Curry

<curry.judith@gmail.com> wrote:

I agree we should have something up front, but not pages. Will propose something more specific

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Ross

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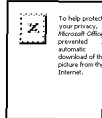
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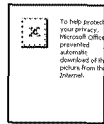
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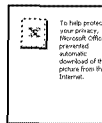
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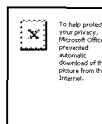
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Subject: Re: Ch 8 Extreme weather
Attachments: ch 8 preamble.docx

See attached for my smash down of section 8.2 (13 down to 2 pages). I included on detection statements (no attribution or projections); focused on AR6 and included some statements from NCA17 and SREX that provided additional detail. I focused on summary statements from the SPM and chapter summaries (without citations of individual papers)

Let me know what you think, and whether you prefer it up front or at the end (maybe an appendix)

On Sat, May 10, 2025 at 11:52 AM Steven Koonin <steven.koonin@gmail.com> wrote:
I like John's suggestion.

Steven E. Koonin

On May 10, 2025, at 14:36, John Christy <climateman60@gmail.com> wrote:

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Would this work. Put the IPCC/NCA quotes in bold up front with a little introductory remark then add "full statements in context in appendix"?

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The extreme weather alarmism angle has been non-stop for years. People are saturated with the message that climate change = extreme weather and all scientists say it's bad and getting worse due to GHGs. It will take a lot of hammering on the theme to convince people how much they've been misled. So I don't mind if the first 15 pages of this chapter consists of mind-numbing repetition of the message that scientists don't say this and have never said it. At this point I want to hold the readers' faces in it until their limbs stop twitching and then they'll be receptive to the rest of the material.

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The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table 12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

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SEK

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2. We have analyses of the CONUS with more complete datasets than the NCA used (recall NCA analyses depended essentially on a small group at NCEI using datasets that (a) were not very consistent in time, (b) could promote alarm and (c) already easy for them to get to. Our datasets have literally hundreds of thousands of manually keyed-in observations for temporal consistency. In other words, this lets people know we can address these issues from soup to nuts - we're not armchair climate scientists ... we can reproduce what they did, but make the analysis more comprehensive to address the questions.

John C.

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On May 6, 2025, at 4:14 AM, Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

Just read your attribution chapter. I hadn't picked up on the gap between IPCC Ch 11 vs Ch 12 language but i see your point that rather than promoting one set of attribution findings we should explain that even within the same AR different authors assessed things differently. One option is to leave Ch 6 where it is but reverse the order of Ch 7 and 8 while retitling the latter as you suggest. That way, having established the extreme weather types for which there are no detectable trends it will more naturally follow that they won't be discussed in the attribution chapter.

On Tue, May 6, 2025 at 9:45 AM Judith Curry <curry.judith@gmail.com> wrote:

Ok, but the summary table (12.12 from AR6) is inconsistent with conclusions in AR6 ch 11 (I point this out in section 6.4 of my attribution chapter).

In my mind, the main point is disagreement and ambiguity I would suggest chapter 8 going before chapter 6, retitling it as US Weather and Climate Extremes, and make it more of a data chapter, not an attribution chapter (I would put table 12.12 in the attribution chapter if you want to include the actual table)

On Tue, May 6, 2025 at 6:39 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I like john's material too which is why I included it and am working on the extended regional analyses. But on this topic people are heavily primed to believe that extreme weather of all kinds is getting worse due to climate change. The assertion shows up everywhere climate change is discussed including in academic papers. I think it is very valuable to show people that neither the IPCC nor the NCA support such this view. We should at least lead off with the summary table. The library of quotes can go to an appendix but I have found in my public speaking that they have considerable persuasive force for most people. We also need to address floods, droughts, hurricane landfalls, tornadoes etc. I don't see any reason to delete all that material.

On Tue, May 6, 2025 at 9:22 AM Judith Curry <curry.judith@gmail.com> wrote:

I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes" I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable severe weather event.

John's version meshes very well with my version of chapter 6. Read especially section 6.4 of my chapter. I note a discrepancy between chapters 11 and 12 in terms of detecting and attributing

extreme events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the problems/challenges, and topics that are particularly relevant for the US

On Mon, May 5, 2025 at 7:47 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I have wrangled the extreme weather chapter into something I hope flows better and is more readable. I adopted Judy's editorial changes and then the new changes I made are in red. I added some new Figures showing results on PC and SE data and will add the NE chart when I get the data. I also made some labeling suggestions including for the 3 rainfall charts that are hard to understand. Section summaries and an overall summary are still needed.

Ross

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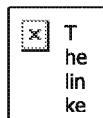
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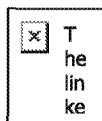
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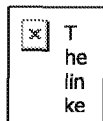
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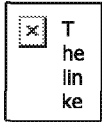
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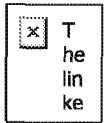
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8.2 Review of IPCC and NCA Findings

The sources reviewed are denoted as follows:

SREX: The IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (2012)

AR6: The IPCC *Sixth Assessment Report Working Group I* (2021).

NCA17: The *US Climate Science Special Report of the Fourth National Climate Assessment* (2017) Volume I Chapter 6.

We present summary statements from these assessment reports that are related to detecting change in extreme weather, both globally and in the US. The focus is on the AR6; other reports are cited for additional insights.

8.2.1 Temperature extremes

AR6: “It is *virtually certain* that hot extremes (including heatwaves) have become **more frequent** and **more intense** across most land regions since the 1950s, while cold extremes (including cold waves) have become less frequent and less severe” (SPM, A3.1)

AR6: “In North America, there is very robust evidence for a *very likely* increase in the intensity and frequency of hot extremes and decrease in the intensity and frequency of cold extremes for the whole continent, though there are substantial spatial and seasonal variations in the trends. Minimum temperatures display warming consistently across the continent, while there are more contrasting trends in the annual maximum daily temperatures in parts of the USA.” (Chapter 11, p 1550)

NCA17: “Changes in warm extremes are more nuanced than changes in cold extremes. For instance, the warmest daily temperature of the year **increased** in some parts of the West over the past century, but there were **decreases** in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net **decrease**, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).” (pp. 190-191)

NCA17: “Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a **maximum in the 1930s**.” (pp. 190-191)

8.2.2 Extreme precipitation

AR6: “The frequency and intensity of heavy precipitation events have **increased** since the 1950s over most land area for which observational data are sufficient for trend analysis (high confidence).” (SPM A3.2)

AR6: “In North America, there is robust evidence that the magnitude and intensity of extreme precipitation has *very likely* **increased** since the 1950s. Both [one-day maxima] and [5-day maxima] have significantly increased in North America during 1950-2018 “(Chapter 11, p. 1560)

8.2.2 River floods

AR6: “The SREX assessed *low confidence* for observed changes in the magnitude or frequency of floods at the global scale. This assessment was confirmed by the AR5 report. The SR15 found increases in flood

frequency and extreme streamflow in some regions, but decreases in other regions. . . [H]ydrological literature on observed flood changes is heterogeneous, focusing at regional and sub-regional basin scales, making it difficult to synthesise at the global and sometimes regional scales.” (Chapter 11.5)

AR6: “[T]he seasonality of floods has changed in cold regions where snowmelt dominates the flow regime in response to warming (*high confidence*). Confidence about peak flow trends over past decades on the global scale is *low*.” (Chapter 11.5)

NCA17: “Trends in extreme high values of streamflow are **mixed** across the United States. Analysis of 200 U.S. stream gauges indicates areas of both increasing and decreasing flooding magnitude but does not provide robust evidence that these trends are attributable to human influences” (pp. 240-241)

8.2.3 Droughts

AR6: “**Few** AR6 regions show observed increases in meteorological drought” (Section 11.9, p. 1575),

AR6: “Increasing trends in agricultural and ecological droughts have been observed on all continents (*medium confidence*), but decreases only in one AR6 region (*medium confidence*). Increasing trends in hydrological droughts have been observed in a few AR6 regions.” (Chapter 11 Summary)

NCA17: “As a consequence of this increased precipitation, drought statistics over the entire CONUS have **declined**.” (p. 233)

NCA17: “Recent droughts and associated heat waves have reached record intensity in some regions of the United States; however, by geographical scale and duration, the Dust Bowl era of the **1930s remains the benchmark** drought and extreme heat event in the historical record (very high confidence).” (p.231)

SREX: “From a paleoclimate perspective, recent droughts are **not unprecedented**, with severe ‘megadroughts’ reported in the paleoclimatic record for Europe, North America, and Australia.” (p. 170)

8.2.4 Hurricanes and Tropical Cyclones (TCs)

AR6: There is *low confidence* in most reported long-term (multidecadal to centennial) trends in TC frequency or intensity-based metrics due to changes in the technology used to collect the best-track data. (Chapter 11, p. 1585)

AR6: It is *likely* that the global proportion of major (Category 3–5) tropical cyclone occurrence has **increased** over the last four decades . . . There is *low confidence* in long-term (multi-decadal to centennial) trends in the frequency of all-category tropical cyclones. (SPM A.3.4)

AR6: A subset of the best-track data corresponding to hurricanes that have directly impacted the United States since 1900 is considered to be reliable, and shows **no trend in the frequency of U.S. landfall events**. (Chapter 11 Summary, p. 1585)

8.2.5 Tornadoes and severe convective storms

AR6: [O]bservational trends in tornadoes, hail, and lightning associated with severe convective storms are **not robustly detected** due to insufficient coverage of the long-term observations. There is *medium confidence* that the mean annual number of tornadoes in the USA has remained relatively constant. (Chapter 11, section 11.7.3, p. 1594)

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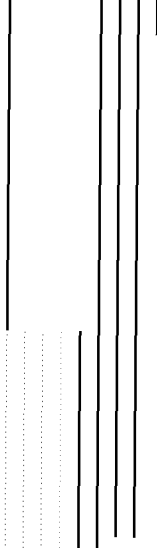
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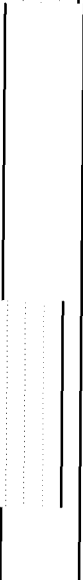
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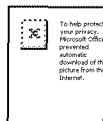
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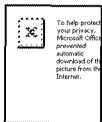
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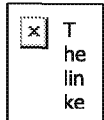


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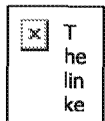
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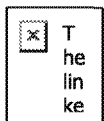
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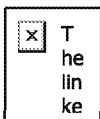
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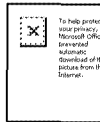
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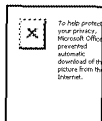
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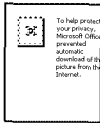
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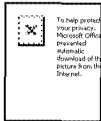
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To: Steven Koonin; Ross McKitrick
Cc: Judith Curry; John Christy; Travis Fisher
Subject: RE: Ch 8 Extreme weather

Regarding Ross' annoyance i can only say, I approve of this message.
Roy

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

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Date: 5/10/25 10:37 AM (GMT-06:00)
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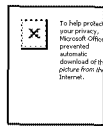
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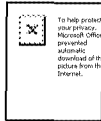
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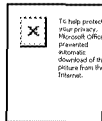
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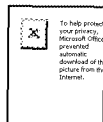
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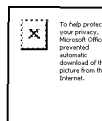
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I'm working on CH 8 Extreme Weather front end today, more soon

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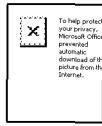
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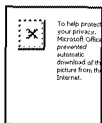
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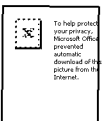
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To: Judith Curry
Cc: Steven Koonin; John Christy; Roy W. Spencer; Travis Fisher
Subject: Re: Ch 8 Extreme weather

This just appeared in the Daily Mail
<https://www.dailymail.co.uk/sciencetech/article-14686539/climate-change-affect-YOU-heatwaves-floods.html>

The extreme weather alarmism angle has been non-stop for years. People are saturated with the message that climate change = extreme weather and all scientists say it's bad and getting worse due to GHGs. It will take a lot of hammering on the theme to convince people how much they've been misled. So I don't mind if the first 15 pages of this chapter consists of mind-numbing repetition of the message that scientists don't say this and have never said it. At this point I want to hold the readers' faces in it until their limbs stop twitching and then they'll be receptive to the rest of the material.

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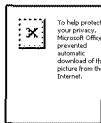
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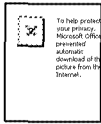
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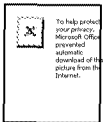
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I have this para in the attribution chapter

The IPCC AR6 provides an ambiguous assessment of the role of global warming in the historical record of extreme weather and climate events. Chapter 11 of WG1 states (Seneviratne et al., 2021):

“Evidence of observed changes in extremes and their attribution to human influence (including greenhouse gas and aerosol emissions and land-use changes) has strengthened since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound extremes (including dry/hot events and fire weather). Some recent hot extreme events would have been extremely unlikely to occur without human influence on the climate system.”

By contrast, Chapter 12 of WG1 (Table 12.12) paints a different picture – presumably, the expert judgment of different groups of authors for the two chapters came to different conclusions (Ranasinghe, 2021):

- High confidence in an increase in extreme heat events in tropical regions where observations allow trend estimation and in most regions in the mid-latitudes, medium confidence elsewhere
- Medium confidence in a decrease in extreme cold events in Australia, Africa and most of northern South America where observations allow trend estimation
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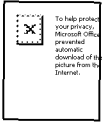
Ross

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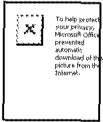
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Sent: 5/9/2025 6:45:24 PM
To: Roy Spencer [roywspencer@hotmail.com]
CC: Judith Curry [curry.judith@gmail.com]; John Christy [climatemanager60@gmail.com]; Steven Koonin [steven.koonin@gmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]
Subject: Re: Ch 8 Extreme weather
Attachments: 8 Extreme weather.May09[RM].docx

In the attached Extreme Weather chapter draft I moved the IPCC/NCA excerpts back into the main body per the discussion here and renumbered all the sections and figures mutatis mutandis.

The AI summary is not bad but does need some work. Admittedly it's a lot of stuff to summarize, although the recurring theme is that trends aren't detectable and attribution to GHGs is currently not possible, in general.

On Thu, May 8, 2025 at 1:45 PM Roy Spencer <roywspencer@hotmail.com> wrote:

This way forward is fine with me.

-Roy

From: Judith Curry <curry.judith@gmail.com>

Sent: Thursday, May 8, 2025 12:43 PM

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Subject: Re: Ch 8 Extreme weather

I think starting with IPCC up front is very useful to provide a reference point, and discussing problems with NCA motivates the unpublished data analysis

On Thu, May 8, 2025 at 10:36 AM John Christy <climatemanager60@gmail.com> wrote:

Ultimately the order will likely not matter. We are somewhat conflicted. On one hand we show the Assessments are consistent with our conclusions about extreme weather, but on the other hand we find them (especially NCAs) deceptive in presenting the information that skews their results to lean toward alarmism. This is true of other chapters as well.

At the least we should mention this nuance perhaps up front.

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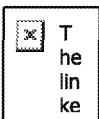
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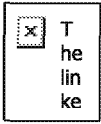
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8 Extreme weather in the US and elsewhere

8.1 Introduction

Weather extremes, usually related to temperature and/or precipitation, can disrupt infrastructure and therefore endanger human health and wellbeing. The issue is not whether extremes occur, for they are intrinsic to the chaotic climate system. Rather, it is whether there are long-term (decadal scale) changes in the frequency or character of extremes (“detection”), as well as the extent to which such changes and the attendant changes in hazards are caused by anthropogenic emissions of greenhouse gases (“attribution”; e.g., IPCC AR6 Seneviratne et al. 2021).

It is naïve to assume that any recent unprecedented extreme event is caused by human influences on the climate. That assumption is wrong in two ways. First, climate is about the statistical properties of weather over decades, not single events. And second, there are only about 130 years of reliable observational records that can be analyzed statistically. That brief interval does not begin to contain all of the extreme events that the climate system can create on its own. Over geologic time the climate system has generated an (essentially) infinite variety of weather patterns and extremes that humans have never observed, and thus are absent from the databases used to determine extreme statistics.¹ [see *Perils of short data records* below]. For that reason, attributing an extreme event unprecedented in the record requires assumptions about the magnitude of natural variations.

This is especially true for precipitation events. The hydrological literature has long noted the phenomenon of *Long Term Persistence* (LTP) in rainfall data (Hurst 1951, Cohn and Lins 2005, Markonis and Koutsoyiannis 2015). LTP has a formal mathematical definition but it can be thought of intuitively as the presence of natural variations with strong autocorrelation properties that result in cycle-like behavior on long time scales. The presence of LTP requires long records to accurately estimate variability. Analysis of records short relative to the LTP scale will tend to underestimate variability, therefore overstating the significance of apparent trends and underestimating the likelihood of extreme events (Cohn and Lins 2005).

A good example of LTP is the eight-century long record of the annual minimum height of the Nile River observed at Roda Island in Cairo shown below in Figure 8.1.1. Since human influences on the global climate were negligible before the 20th century, the century-scale variability of the thirty-year average is entirely natural; Egyptians of the seventh and eight centuries would have been incorrect to assume that the worsening drought during that time was the “new normal.”

¹ For example, under the simplest statistical assumptions there is a 37 percent chance that a 100-year event is NOT present in a century-long record.

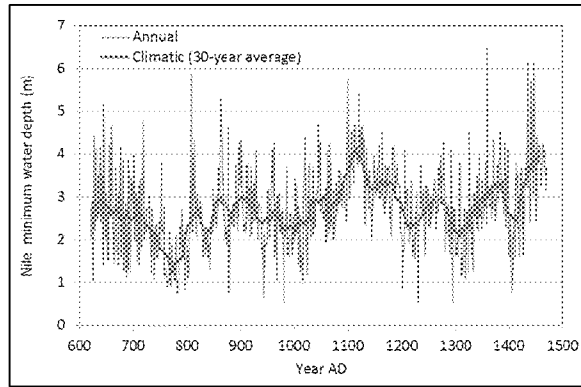


Figure 8.1.1: Nile River discharge [details, source]

With these caveats in mind we examine the evidence for changes in selected weather and climate extremes. It has become routine in media discussions, government and private sector discussions and even in some academic literature to make generalized assertions that extreme weather of all types is getting worse due to GHGs and climate change. Yet expert assessments have not typically drawn such sweeping conclusions and instead have emphasized the difficulty both of identifying specific trends and establishing a causal connection with anthropogenic forcing. For the benefit of readers who may not have read the relevant reports we will begin with extended excerpts of findings from previous IPCC and NCA assessments, then in the remainder of this chapter survey additional data relevant to US and global extreme weather trends.

8.2 Review of IPCC and NCA Findings on Extreme Weather

The sources we review will be denoted as follows:

SREX: The IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (2012)

AR5: The IPCC *Fifth Assessment Report Working Group 1* (2013).

AR6: The IPCC *Sixth Assessment Report Working Group 1* (2021).

NCA17: The *US Climate Science Special Report of the Fourth National Climate Assessment* (2017) Volume I Chapter 6.

8.2.1 Overview: IPCC Assessment of signal emergence in extreme weather types (AR6 WG1 Table 12.12)

Table 8.2.1 reproduces the findings of AR6 Table 12.12 which indicates, for 34 major weather event and impact types, whether a signal of anthropogenic forcing has been detected in the historical record (column 1), whether such a signal is likely to emerge by 2050 under the extreme RCP8.5 scenario (column 2) and whether it is likely to emerge by 2100 under RCP8.5 forcing (column 3). It should be borne in mind that the latter two columns suffer from the deficiencies of GCMs discussed in Chapter XX. And as we discussed in Ch X on attribution, AR6 offers conflicting messages about attribution of extreme weather. Nevertheless, we provide this Table for reference.

Several patterns stand out. First, detection of an anthropogenic signal is asserted with *high confidence* in only four of the 34 weather impact categories, and with *medium confidence* in a

further four. The IPCC does NOT claim to have detected an anthropogenic signal in the remaining 26 categories. Of the four *high confidence* assertions, two are for changes in average temperatures (air and ocean), which are not measures of extreme weather. Further, two of the four *medium confidence* assertions are related to ocean chemistry and also not related to extreme weather. The IPCC does NOT assert a detectable human influence on many non-temperature weather features such as wind, precipitation, flooding, and drought.

Second, columns 2 and 3 show that the IPCC expects very few anthropogenic trends to emerge within this century, *even under the most extreme forcing scenario*. As we discuss in Section 4.2 the RCP8.5 scenario is an implausible high-end storyline, not a “base case” or “business-as-usual” projection. Even so, most weather impacts are not expected to show an anthropogenic signal this century. Natural variability dominates patterns of extreme weather systems and simplistic assertions of trend detection are frequently undermined by regional heterogeneity and trend reversals over time.

Climate Impact Driver Type	Climate Impact Driver Category	Already Emerged in the Historical Record?	Emerging by 2050 in Most Extreme CO2 Emissions Scenario?	Emerging by 2100 in Most Extreme CO2 Emissions Scenario?
Heat & Cold	Average air temperature	YES in most regions	YES	YES
	More heat extremes	YES in most regions	YES in land regions	YES
	Fewer cold extremes	YES in a few regions	YES in many regions	YES
	Less frost	NO	NO	NO
Wet & Dry	Average Precip. (Increase or Decrease)	NO	YES (incr) YES (decr)	YES (incr) YES (decr)
	River flooding	NO	NO	NO
	Heavy precip & pluvial flood	NO	NO	YES in a few regions
	Landslide	NO	NO	NO
	Aridity	NO	NO	NO
	Hydrologic Drought	NO	NO	NO
	Agricultural & ecological drought	NO	NO	NO
	Fire weather	NO	NO	NO
Wind	Average wind speed	NO	NO	NO
	Severe wind storm	NO	NO	NO
	Tropical cyclone	NO	NO	NO
	Sand and dust storm	NO	NO	NO
Snow and Ice	Snow, glacier & ice sheet	NO	YES in a few regions	YES Arctic snow
	Permafrost	YES	YES	YES
	Lake & river ice	NO	YES	YES
	Arctic sea ice	YES	YES	YES
	Antarctic sea ice	NO	YES	YES
	Heavy snowfall and ice storm	NO	NO	NO
	Hail	NO	NO	NO
	Snow avalanche	NO	NO	NO
Coastal	Relative sea level	NO	YES	YES
	Coastal flood	NO	NO	NO
	Coastal erosion	NO	NO	NO
Open Ocean	Average ocean temperature	YES	YES	YES
	Marine heat wave	NO	NO	NO
	Ocean acidity	NO	YES	YES
	Ocean salinity	YES	YES	YES
	Dissolved oxygen	YES (Pacific & S. Ocean)	YES	YES
Other	Air pollution weather	NO	NO	NO
	Solar or IR radiation at surface	NO	NO	NO

Table 8.2.1. IPCC AR6 summary of the probable emergence of an anthropogenic signal above natural climate variability for all global or regional “climate impact drivers” (CIDs) of concern for humans and ecosystems in response to increasing atmospheric greenhouse gas concentrations (primarily CO₂). Source: Table adapted from report of Working Group I, Table 12.12). Red = high confidence; yellow = medium confidence; green = no anthropogenic signal detectable above natural variability (50% confidence).

Taking wind as an example, the IPCC claims that an anthropogenic signal has NOT emerged in average wind speeds, severe windstorms, tropical cyclones, or sand and dust storms, and none are expected to emerge this century even under an extreme emissions scenario. The same applies to drought and fire weather. This table alone suffices to illustrate the gap between IPCC expert assessments of extreme weather and discussions in the popular media and political arenas. As we show below the Table reflects longstanding conclusions of the IPCC and other assessment bodies. In the next few sections we will simply present without comment excerpts from past assessment reports.² In selecting these excerpts, we’ve focused on the highest-level summaries to avoid accusations of bias through “cherry picking”.

² In these excerpts we have added **bold-face** emphasis, while *italicized* emphasis on confidence terms appears in the original sources. Citations in quoted text can be found in the underlying reports but are not reproduced here.

8.2.2 Flooding

SREX (p. 176)

In the United States and Canada during the 20th century and in the early 21st century, **there is no compelling evidence for climate-driven changes in the magnitude or frequency of floods.**

AR5 (p. 214)

AR4 WGI Chapter 3 (Trenberth et al., 2007) did not assess changes in floods but AR4 WGII concluded that **there was not a general global trend in the incidence of floods** (Kundzewicz et al., 2007). SREX went further to suggest that there was low agreement and thus *low confidence* at the global scale regarding changes in the magnitude or frequency of floods or even the sign of changes.

AR5 WGII assesses floods in regional detail accounting for the fact that trends in floods are strongly influenced by changes in river management (see also Section 2.5.2). Although the most evident flood trends appear to be in northern high latitudes, where observed warming trends have been largest, in some regions no evidence of a trend in extreme flooding has been found, for example, over Russia based on daily river discharge (Shklomanov et al., 2007). Other studies for Europe (Hannaford and Marsh, 2008; Renard et al., 2008; Petrow and Merz, 2009; Stahl et al., 2010) and Asia (Jiang et al., 2008; Delgado et al., 2010) show evidence for upward, downward or no trend in the magnitude and frequency of floods, so that there is currently no clear and widespread evidence for observed changes in flooding except for the earlier spring flow in snow-dominated regions (Seneviratne et al., 2012).

In summary, **there continues to be a lack of evidence and thus *low confidence* regarding the sign of trend in the magnitude and/or frequency of floods on a global scale.**

AR6 (Ch 11 p. 1568)

The SREX (Seneviratne et al., 2012) assessed *low confidence* for observed changes in the magnitude or frequency of floods at the global scale. This assessment was confirmed by the AR5 report (Hartmann et al., 2013). The SR15 (Hoegh-Guldberg et al., 2018) found increases in flood frequency and extreme streamflow in some regions, but decreases in other regions. **While the number of studies on flood trends has increased since the AR5 report, and there were also new analyses after the release of SR15 (Berghuijs et al., 2017; Blöschl et al., 2019; Gudmundsson et al., 2019), hydrological literature on observed flood changes is heterogeneous, focusing at regional and sub-regional basin scales, making it difficult to synthesise at the global and sometimes regional scales.**

In summary, the seasonality of floods has changed in cold regions where snowmelt dominates the flow regime in response to warming (*high confidence*). **Confidence about peak flow trends over past decades on the global scale is low, but there are regions experiencing increases**, including parts of Asia, southern South America, the northeast USA, northwestern Europe, and the Amazon, **and regions experiencing decreases**, including parts of the Mediterranean, Australia, Africa, and the southwestern USA.

US NCA17 pp. 240-41:

“The IPCC AR5 did not attribute changes in flooding to anthropogenic influence nor report detectable changes in flooding magnitude, duration, or frequency. Trends in extreme high values of streamflow are mixed across the United States. Analysis of 200 U.S. stream gauges

indicates areas of both increasing and decreasing flooding magnitude but does not provide robust evidence that these trends are attributable to human influences...

The complex mix of processes complicates the formal attribution of observed flooding trends to anthropogenic climate change and suggests that additional scientific rigor is needed in flood attribution studies. As noted above, precipitation increases have been found to strongly influence changes in flood statistics. However, in U.S. regions, **no formal attribution of precipitation changes to anthropogenic forcing has been made so far, so indirect attribution of flooding changes is not possible. Hence, no formal attribution of observed flooding changes to anthropogenic forcing has been claimed.**"

8.2.3 Heatwaves

AR5 (p. 212 WG1)

Table 2.13 shows that there has been a *likely* increasing trend in the frequency of heatwaves since the middle of the 20th century in Europe and Australia and across much of Asia where there are sufficient data. However, confidence on a global scale is *medium* owing to lack of studies over Africa and South America but also in part owing to differences in trends depending on how heatwaves are defined (Perkins et al., 2012). Using monthly means as a proxy for heatwaves Coumou et al. (2013) and Hansen et al. (2012) indicate that record-breaking temperatures in recent decades substantially exceed what would be expected by chance but caution is required when making inferences between these studies and those that deal with multi-day events and/ or use more complex definitions for heatwave events. **There is also evidence in some regions that periods prior to the 1950s had more heatwaves (e.g., over the USA, the decade of the 1930s stands out and is also associated with extreme drought conditions** (Peterson et al., 2013) whereas conversely in other regions heatwave trends may have been underestimated owing to poor quality and/or consistency of data (e.g., Della-Marta et al. (2007a) over Western Europe; Kuglitsch et al. (2009, 2010) over the Mediterranean). Recent available studies also suggest that the number of cold spells has reduced significantly since the 1950s (Donat et al., 2013a, 2013c).

In summary, new analyses continue to support the AR4 and SREX conclusions that since about 1950 it is *very likely* that the numbers of cold days and nights have decreased and the numbers of warm days and nights have increased overall on the global scale, that is, for land areas with sufficient data. It is *likely* that such changes have also occurred across most of North America, Europe, Asia and Australia.

NCA17 (pp. 190-191)

Changes in warm extremes are more nuanced than changes in cold extremes. For instance, **the warmest daily temperature of the year increased in some parts of the West over the past century (Figure 6.3), but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease** (Table 6.2), most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]). The decreases in the eastern half of [the] Nation, particularly in the Great Plains, are mainly tied to the unprecedented summer heat of the 1930s Dust Bowl era, which was exacerbated by land-surface feedbacks driven by springtime precipitation deficits and land mismanagement. However, anthropogenic aerosol forcing may also have reduced summer temperatures in the Northeast and Southeast from the early 1950s to the mid-1970s, and agricultural intensification may have suppressed the hottest extremes in the Midwest.

Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). **Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter (Figure 6.4).** As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s.

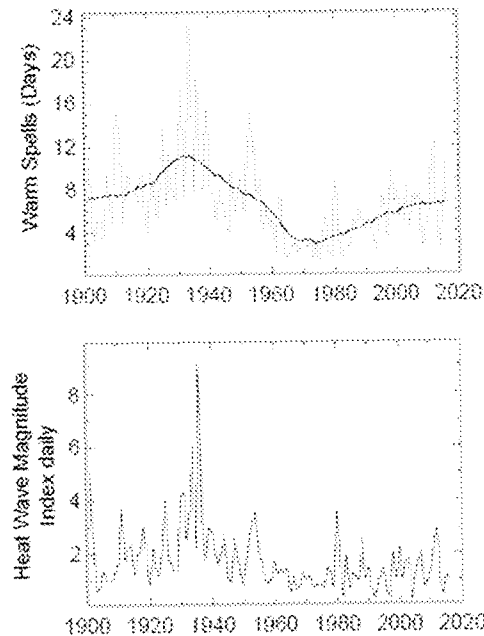


Figure 8.2.1: US Heat waves since 1900. Source: NCA17 Figure 6.4

AR6 (p. 1550)

In North America (Table 11.19), there is very robust evidence for a *very likely* increase in the intensity and frequency of hot extremes and decrease in the intensity and frequency of cold extremes for the whole continent, though there are substantial spatial and seasonal variations in the trends. Minimum temperatures display warming consistently across the continent, **while there are more contrasting trends in the annual maximum daily temperatures** in parts of the USA (Figure 11.9; Lee et al., 2014; van Oldenborgh et al., 2019; Dunn et al., 2020).

8.2.4 Extreme snowfall events

Note: extreme snowfall events in the US northeast are assessed in relation to winter Extratropical Cyclone (ETC) activity.

AR6 Ch 11. p. 1593

There is *high confidence* that snowfall associated with winter ETCs will decrease in the future, because increases in tropospheric temperatures lead to a lower proportion of precipitation falling as snow (O’Gorman, 2014; Rhoades et al., 2018; Zarzycki, 2018). However, there is

medium confidence that extreme snowfall events associated with winter ETCs will change little in regions where snowfall will be supported in the future (O’Gorman, 2014; Zarzycki, 2018).

8.2.5 Extreme precipitation

SREX (p. 142)

Recent studies have updated the assessment of the AR4, with more regional results now available (Table 3-2). Overall, this additional evidence confirms that **more locations and studies show an increase than a decrease in extreme precipitation, but that there are also wide regional and seasonal variations**, and trends in many regions are not statistically significant (Table 3-2)... Based on station data from Canada, the United States, and Mexico, Peterson et al. (2008a) reported that heavy precipitation has been increasing over 1950-2004, as well as the average amount of precipitation falling on days with precipitation.

AR5 (pp. 213-14)

In summary, further analyses continue to support the AR4 and SREX conclusions that **it is likely that since 1951 there have been statistically significant increases in the number of heavy precipitation events (e.g., above the 95th percentile) in more regions than there have been statistically significant decreases, but there are strong regional and subregional variations in the trends**. In particular, many regions present statistically non-significant or negative trends, and, where seasonal changes have been assessed, there are also variations between seasons (e.g., more consistent trends in winter than in summer in Europe). The overall most consistent trends towards heavier precipitation events are found in central North America (very likely increase) but assessment for Europe shows likely increases in more regions than decreases.

AR6 (p. 1560)

In North America, there is robust evidence that the magnitude and intensity of extreme precipitation has *very likely* increased since the 1950s. Both [one-day maxima] and [5-day maxima] have significantly increased in North America during 1950-2018 (Sun et al., 2020, also Figure 11.13). There is, however, regional diversity. In Canada, there is a lack of detectable trends in observed annual maximum daily (or shorter duration) precipitation (Shephard et al., 2014; Mekis et al., 2015; Vincent et al., 2018).

NCA17 pp. 213-14:

Detectability of trends (compared to internal variability) for a number of precipitation metrics over the continental United States has been examined; **however, trends identified for the U.S. regions have not been clearly attributed to anthropogenic forcing**. One study concluded that increasing precipitation trends in some north-central U.S. regions and the extreme annual anomalies there in 2013 were at least partly attributable to the combination of anthropogenic and natural forcing... **Based on current evidence, it is concluded that detectable but not attributable increases in mean precipitation have occurred over parts of the central United States**. Formal detection-attribution studies indicate a human contribution to extreme precipitation increases over the continental United States, but confidence is *low* based on those studies alone due to the short observational period, high natural variability, and model uncertainty.

In summary, based on available studies, it is concluded that for the continental United States there is *high confidence* in the detection of extreme precipitation increases, while there is *low confidence* in attributing the extreme precipitation changes purely to anthropogenic forcing.

8.2.6 Tornadoes and severe convective storms

IPCC AR6 Sct. 11.7.3, p. 1594

Severe convective storms are convective systems that are associated with extreme phenomena such as tornadoes, hail, heavy precipitation (rain or snow), strong winds, and lightning.

The assessment of changes in severe convective storms in SREX (Chapter 3, Seneviratne et al., 2012) and AR5 (Chapter 12, Collins et al., 2013) is limited and focused mainly on tornadoes and hail storms. The SREX assessed that **there is *low confidence* in observed trends in tornadoes and hail** because of data inhomogeneities and inadequacies in monitoring systems. Subsequent literature assessed in the Climate Science Special Report (Kossin et al., 2017) led to the assessment of the observed tornado activity over the 2000s in the USA, with a decrease in the number of days per year with tornadoes and an increase in the number of tornadoes on these days (*medium confidence*). However, **there is *low confidence* in past trends for hail and severe thunderstorm winds**. Climate models consistently project environmental changes that would support an increase in the frequency and intensity of severe thunderstorms that combine tornadoes, hail, and winds (*high confidence*), but there is *low confidence* in the details of the projected increase.

... In summary, because the definition of severe convective storms varies depending on the literature and the region, it is not straightforward to make a synthesizing view of observed trends in severe convective storms in different regions. In particular, **observational trends in tornadoes, hail, and lightning associated with severe convective storms are not robustly detected** due to insufficient coverage of the long-term observations. There is *medium confidence* that the mean annual number of tornadoes in the USA has remained relatively constant, but their variability of occurrence has increased since the 1970s, particularly over the 2000s, with **a decrease in the number of days per year, and an increase in the number of tornadoes on these days** (*high confidence*). Detected tornadoes have also increased in Europe, but the trend depends on the density of observations.

... In summary, **it is extremely difficult to detect and attribute changes in severe convective storms**. There is limited evidence that extreme precipitation associated with severe convective storms has increased in some cases.

8.2.7 Hurricanes and Tropical Cyclones

SREX (p. 159):

There have been no significant trends observed in global tropical cyclone frequency records, including over the present 40-year period of satellite observations (e.g., Webster et al., 2005). Regional trends in tropical cyclone frequency have been identified in the North Atlantic, but the fidelity of these trends is debated (Holland and Webster, 2007; Landsea, 2007; Mann et al., 2007a). Different methods for estimating undercounts in the earlier part of the North Atlantic tropical cyclone record provide mixed conclusions (Chang

and Guo, 2007; Mann et al., 2007b; Kunkel et al., 2008; Vecchi and Knutson, 2008). Regional trends have not been detected in other oceans (Chan and Xu, 2009; Kubota and Chan, 2009; Callaghan and Power, 2011). **It thus remains uncertain whether any observed increases in tropical cyclone frequency on time scales longer than about 40 years are robust**, after accounting for past changes in observing capabilities (Knutson et al., 2010).

AR5 (pp. 216-17):

Current data sets indicate no significant observed trends in global tropical cyclone frequency over the past century and it remains uncertain whether any reported long-term increases in tropical cyclone frequency are robust, after accounting for past changes in observing capabilities (Knutson et al., 2010). **No robust trends in annual numbers of tropical storms, hurricanes and major hurricanes counts have been identified** over the past 100 years in the North Atlantic basin. Measures of land-falling tropical cyclone frequency (Figure 2.34) are generally considered to be more reliable than counts of all storms which tend to be strongly influenced by those that are weak and/or short lived. Callaghan and Power (2011) find a statistically significant decrease in Eastern Australia land-falling tropical cyclones since the late 19th century although including 2010/2011 season data this trend becomes non-significant (i.e., a trend of zero lies just inside the 90% confidence interval). Significant trends are not found in other oceans on shorter time scales (Chan and Xu, 2009; Kubota and Chan, 2009; Mohapatra et al., 2011; Weinkle et al., 2012), although Grinstead et al. (2012) find a significant positive trend in eastern USA using tide-gauge data from 1923–2008 as a proxy for storm surges associated with land-falling hurricanes. Differences between tropical cyclone studies highlight the challenges that still lie ahead in assessing long-term trends.

In summary, this assessment does not revise the SREX conclusion of *low confidence* that any reported long-term (centennial) increases in tropical cyclone activity are robust, after accounting for past changes in observing capabilities. More recent assessments indicate that **it is unlikely that annual numbers of tropical storms, hurricanes and major hurricanes counts have increased over the past 100 years in the North Atlantic basin**. Evidence, however, is for a virtually certain increase in the frequency and intensity of the strongest tropical cyclones since the 1970s in that region.

AR6 (p. 1585)

There is low confidence in most reported long-term (multidecadal to centennial) trends in TC frequency- or intensity-based metrics due to changes in the technology used to collect the best-track data. This should not be interpreted as implying that no physical (real) trends exist, but rather as indicating that either the quality or the temporal length of the data is not adequate to provide robust trend detection statements, particularly in the presence of multidecadal variability.

There are previous and ongoing efforts to homogenize the best-track data (Elsner et al., 2008; Kossin et al., 2013, 2020; Choy et al., 2015; Landsea, 2015; Emanuel et al., 2018) and there is substantial literature that finds positive trends in intensity-related metrics in the best-track during the “satellite period”, which is generally limited to the past ~40 years (Kang and Elsner, 2012; Kishtawal et al., 2012; Kossin et al., 2013, 2020; Mei and Xie, 2016; Zhao et al., 2018; Tauvale and Tsuboki, 2019). **When best-track trends are tested using homogenized data, the intensity trends generally remain positive, but are smaller in amplitude** (Kossin et al., 2013; Holland and Bruyère, 2014). **Kossin et al. (2020) extended the homogenized TC intensity record to the period 1979–2017 and identified significant**

global increases in major TC exceedance probability of about 6% per decade.³ In addition to trends in TC intensity, there is evidence that TC intensification rates and the frequency of rapid intensification events have increased within the satellite era (Kishtawal et al. 2012; Balaguru et al., 2018; Bhatia et al., 2018). The increase in intensification rates is found in the best-track as well as the homogenized intensity data.

A subset of the best-track data corresponding to hurricanes that have directly impacted the United States since 1900 is considered to be reliable, and shows no trend in the frequency of U.S. landfall events (Knutson et al., 2019).

8.2.8 Droughts

US NCA17 REPORT (Ch. 8, Wehner et al. 2017)

p. 231:

Recent droughts and associated heat waves have reached record intensity in some regions of the United States; however, by geographical scale and duration, the Dust Bowl era of the 1930s remains the benchmark drought and extreme heat event in the historical record (very high confidence). **While by some measures drought has decreased over much of the continental United States in association with long-term increases in precipitation, neither the precipitation increases nor inferred drought decreases have been confidently attributed to anthropogenic forcing.**

The human effect on recent major U.S. droughts is complicated. Little evidence is found for a human influence on observed precipitation deficits, but much evidence is found for a human influence on surface soil moisture deficits due to increased evapotranspiration caused by higher temperatures. (*High confidence*)

p. 233:

Drought is, of course, directly connected to seasonal precipitation totals. Figure 7.1 shows detectable observed recent changes in seasonal precipitation. In fact, the increases in observed summer and fall precipitation are at odds with the projections in Figure 7.5. **As a consequence of this increased precipitation, drought statistics over the entire CONUS have declined.**

SREX (p. 170)

From a paleoclimate perspective recent droughts are not unprecedented, with severe ‘megadroughts’ reported in the paleoclimatic record for Europe, North America, and

³ The **underlined** text referenced a study (Kossin et al. 2020) that later retracted a portion of its findings. Those authors assembled a data set on global TC incidence spanning 1979 to 2017 from which they claimed that the global fraction of TCs reaching major status (Cat 3—5) rose from 27% during 1979-1997 to 31% during 1998-2017 and that the increase was statistically significant. However, closer examination of their results showed a significant increase only in the North Atlantic (18% to 34%) whereas changes in all other basins (Eastern Pacific, Western Pacific, North Indian, South Indian, South Pacific) were not statistically significant. In a subsequent correction (<https://www.pnas.org/doi/10.1073/pnas.2021573117>), Kossin et al. stated that the global probability of observing a major TC rose from 34% during 1979-1997 to 37% in the later period and that the evidence for statistical significance was now weaker. Nevertheless, the authors claimed that the correction did not affect their conclusions.

Australia (Jansen et al., 2007). Recent studies extend this observation to African and Indian droughts (Sinha et al., 2007; Shanahan et al., 2009): much more severe and longer droughts occurred in the past centuries with widespread ecological, political, and socioeconomic consequences. Overall, these studies confirm that in the last millennium several extreme droughts have occurred (Breda and Badeau, 2008; Kallis, 2008; Büntgen et al., 2010).

In North America, there is *medium confidence* that there has been an overall slight tendency toward less dryness (wetting trend with more soil moisture and runoff; Table 3-2), although analyses for some subregions also indicate tendencies toward increasing dryness. This assessment is based on several lines of evidence, including simulations with different hydrological models as well as PDSI and CDD estimates (Alexander et al., 2006; Andreadis and Lettenmaier, 2006; van der Schrier et al., 2006a; Kunkel et al., 2008; Sheffield and Wood, 2008a; Dai, 2011).

The most severe droughts in the 20th century have occurred in the 1930s and 1950s, where the 1930s Dust Bowl was most intense and the 1950s drought most persistent (Andreadis et al., 2005) in the United States, while in Mexico the 1950s and late 1990s were the driest periods. Recent regional trends toward more severe drought conditions were identified over southern and western Canada, Alaska, and Mexico, with subregional exceptions (Dai, 2011).

SREX (p. 172)

Overall, though new studies have furthered the understanding of the mechanisms leading to drought, there is still relatively limited evidence to provide an attribution of observed changes, in particular given the issues associated with the availability of observational data (Section 3.2.1) and the definition and computation of drought indicators (Box 3-3). This latter point was mostly identified in post-AR4 studies (Box 3-3). Moreover, regions where consistent increases in drought are identified (see ‘Observed Changes’) are only partly consistent with those where projections indicate an enhancement of drought conditions in coming decades (see next paragraphs). We thus assess that there is *medium confidence* (see also Section 3.1.5) that anthropogenic influence has contributed to some changes in the drought patterns observed in the second half of the 20th century, based on its attributed impact on precipitation and temperature changes (though temperature can only be indirectly related to drought trends; see Box 3-3). However **there is *low confidence* in the attribution of changes in droughts at the level of individual regions.**

AR5 (pp. 214-215)

Based on evidence since AR4, SREX concluded that there were not enough direct observations of dryness to suggest high confidence in observed trends globally, although there was *medium confidence* that since the 1950s some regions of the world have experienced more intense and longer droughts. The differences between AR4 and SREX are due primarily to analyses post-AR4, differences in how both assessments considered drought and updated IPCC uncertainty guidance.

Because drought is a complex variable and can at best be incompletely represented by commonly used drought indices, discrepancies in the interpretation of changes can result. For example, Sheffield and Wood (2008) found decreasing trends in the duration, intensity and severity of drought globally. Conversely, Dai (2011a,b) found a general global increase in drought, although with substantial regional variation and individual events dominating trend signatures in some regions (e.g., the 1970s prolonged Sahel drought and the 1930s drought

in the USA and Canadian Prairies). Studies subsequent to these continue to provide somewhat different conclusions on trends in global droughts and/or dryness since the middle of the 20th century (Sheffield et al., 2012; Dai, 2013; Donat et al., 2013c; van der Schrier et al., 2013).

In summary, the current assessment concludes that there is not enough evidence at present to suggest more than *low confidence* in a global-scale observed trend in drought or dryness (lack of rainfall) since the middle of the 20th century, owing to lack of direct observations, geographical inconsistencies in the trends, and dependencies of inferred trends on the index choice. Based on updated studies, AR4 conclusions regarding global increasing trends in drought since the 1970s were probably overstated. However, it is *likely* that the frequency and intensity of drought has increased in the Mediterranean and West Africa and decreased in central North America and north-west Australia since 1950.

AR6 (Drought, Observed trends, Section 11.6.2, pp. 1573-75)

p. 1573

Strong precipitation deficits have been recorded in recent decades in the Amazon (2005, 2010), south-western China (2009–2010), south-western North America (2011–2014), Australia (1997–2009), California (2014), the middle East (2012–2016), Chile (2010–2015), the Great Horn of Africa (2011), among others (van Dijk et al., 2013; Mann and Gleick, 2015; Rowell et al., 2015; Marengo and Espinoza, 2016; Dai and Zhao, 2017; Garreaud et al., 2017, 2020; Marengo et al., 2017; Brito et al., 2018; Cook et al., 2018). **Global studies generally show no significant trends in SPI time series** (Orlowsky and Seneviratne, 2013; Spinoni et al., 2014), **and in derived drought frequency and severity data** (Spinoni et al., 2019), with very few regional exceptions (Section 11.9 and Figure 11.17).

p. 1574

For AR6 regions, several studies suggest an increase in the frequency and areal extent of soil moisture deficits, with examples in East Asia (Cheng et al., 2015; Y. Qin et al., 2015; Jia et al., 2018), Western and Central Europe (Trnka et al., 2015b), and the Mediterranean (Hanel et al., 2018; Moravec et al., 2019; Markonis et al., 2021). **Nonetheless, some analyses also show no long-term trends in soil drying in some AR6 regions – for example, in Eastern North America (Park Williams et al., 2017) and Central North America** (Seager et al., 2019), as well as in North Eastern Africa (Kew et al., 2021).

There is evidence based on streamflow records of increased hydrological droughts in East Asia (D. Zhang et al., 2018) and southern Africa (Gudmundsson et al., 2019). **In areas of Western and Central Europe and Northern Europe, there is no evidence of changes in the severity of hydrological droughts since 1950** based on flow reconstructions (Caillouet et al., 2017; Barker et al., 2019) and observations (Vicente-Serrano et al., 2019). **In North America, depending on the methods, datasets and study periods, there are differences between studies that suggest an increase (Shukla et al., 2015; Udall and Overpeck, 2017) versus a decrease in hydrological drought frequency (Mo and Lettenmaier, 2018), but in general there is strong spatial variability** (Poshtiri and Pal, 2016). Streamflow observation reference networks of near-natural catchments have also been used to isolate the effect of climate trends on hydrological drought trends in a few regions, but these show limited trends in Northern Europe and Western and Central Europe (Stahl et al., 2010; Bard et al., 2015; Harrigan et al., 2018), North America (Dudley et al., 2020) and most of Australia, with the exception of Eastern and Southern Australia (X.S. Zhang et al., 2016).

p. 1575

Few AR6 regions show observed increases in meteorological drought (Section 11.9), mostly in Africa and South America (NES: *high confidence*; WAF, CAF, ESAF, SAM, SWS, SSA, SAS: *medium confidence*); a few others show a decrease (WSB, ESB, NAU, CAU, NEU, CNA: *medium confidence*). There are stronger signals indicating observed increases in agricultural and ecological drought (Section 11.9), which highlights the role of increased [evapotranspiration], driven by increased [Atmospheric Evaporative Demand], for these trends (Sections 11.6.2.3, 11.6.2.5). Past increases in agricultural and ecological droughts are found on all continents and several regions (WAF, CAF, WSAF, ESAF, WCA, ECA, EAS, SAU, MED, WCE, NES: *medium confidence*), while decreases are found only in one AR6 region (NAU: *medium confidence*). The more limited availability of datasets makes it more difficult to assess historical trends in hydrological drought at regional scale (Section 11.9). Increasing (MED: *high confidence*; WAF, EAS, SAU: *medium confidence*) and decreasing (NEU, SES: *medium confidence*) trends in hydrological droughts have only been observed in a few regions.

AR6 on Attribution (p. 1577)

There are only two AR6 regions in which there is at least *medium confidence* that human-induced climate change has contributed to changes in meteorological droughts (Section 11.9). In South-western South America (SSW), there is *medium confidence* that human-induced climate change has contributed to an increase in meteorological droughts (Boisier et al., 2016; Garreaud et al., 2020), while in Northern Europe (NEU), there is *medium confidence* that it has contributed to a decrease in meteorological droughts (Gudmundsson and Seneviratne, 2016) (Section 11.9). **In other AR6 regions, there is inconclusive evidence in the attribution of long-term trends, but a human contribution to single meteorological events or subregional trends has been identified in some instances... In North America, the human influence on precipitation deficits is complex (Wehner et al., 2017), with low confidence in the attribution of long-term changes in meteorological drought in AR6 regions.**

8.3 Extreme weather trends at global and continental scale

8.3.1 Tropical Cyclones (TCs)

Hurricane strength records for the North Atlantic and the Western Pacific go back to 1950 and the record does not show an increase in either total or major TCs. Figure 8.3.1 was published by Roger Pielke Jr. as an update to the Best Track data series originally presented in Weinkle et al. (2012).

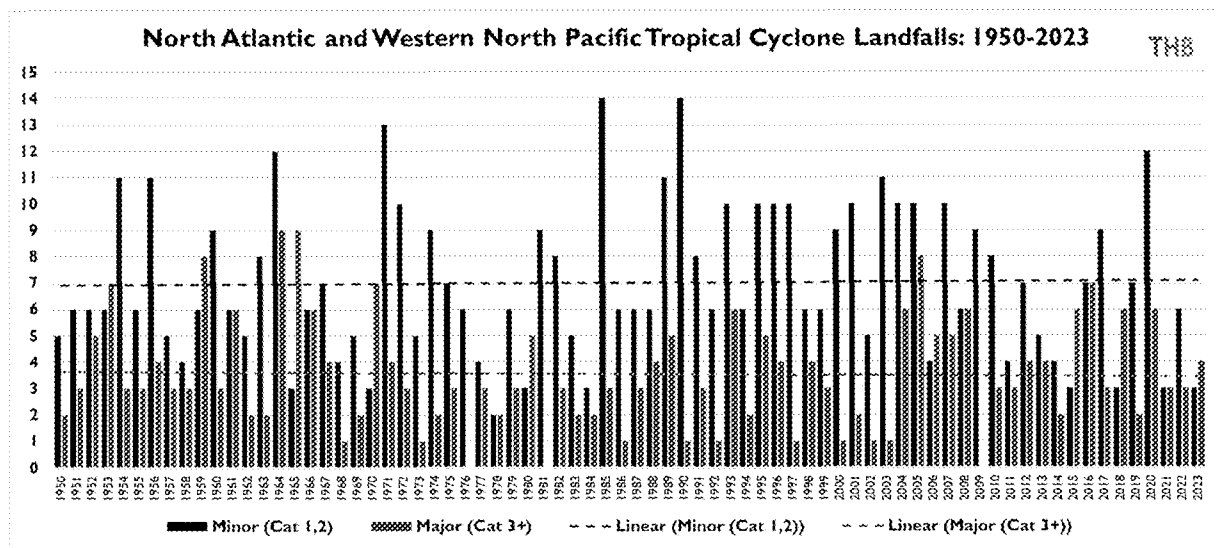


Figure 8.3.1. Tropical Cyclone Landfalls. Source: <https://rogerpielkejr.substack.com/p/global-tropical-cyclones>, Weinkle et al. (2012)

Similarly, Figure 8.3.2 (Maue 2025, <https://climatlas.com/tropical/>) shows that both all hurricanes and major hurricanes have not become more common since 1980, the period of rapidly growing human influences. In fact, both numbers have trended down slightly since the 1990s:

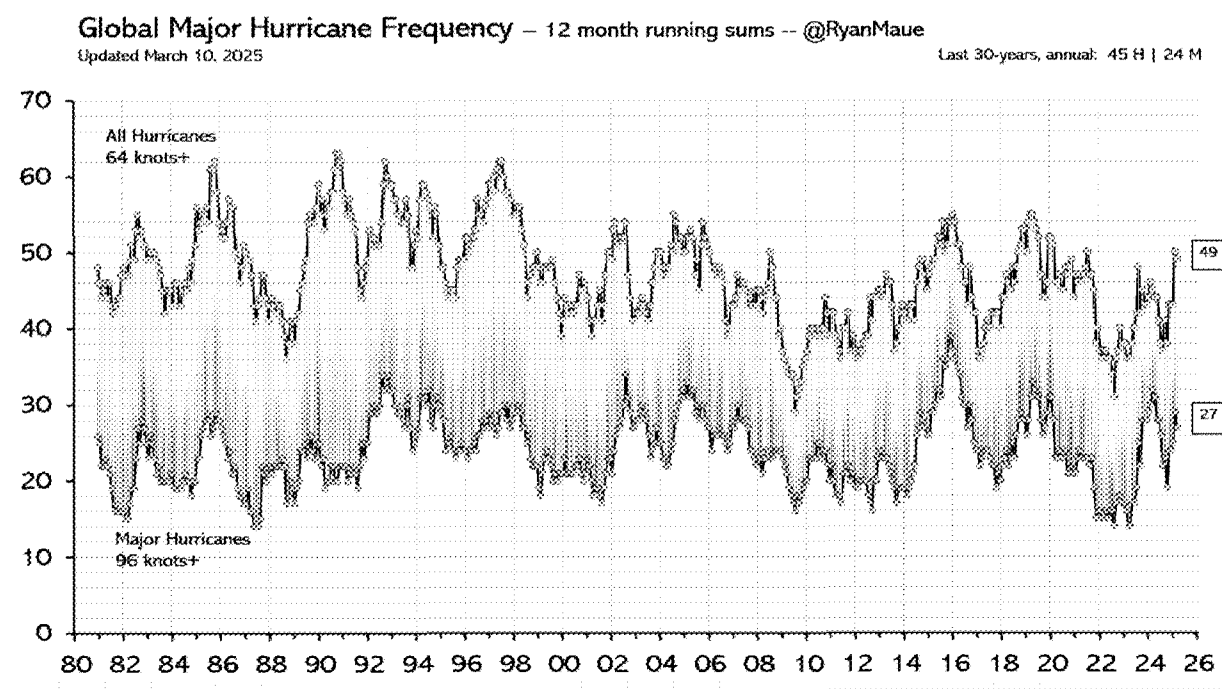


Figure 8.3.2: Global hurricane frequency. Source: Maue (2025)

A metric that combines the number, duration, and strength of TCs is the Accumulated Cyclone Energy (ACE) Index maintained at Colorado State University, shown in Figure 8.3.3. It clearly shows no long-term increase, in fact declining slightly since 1990.

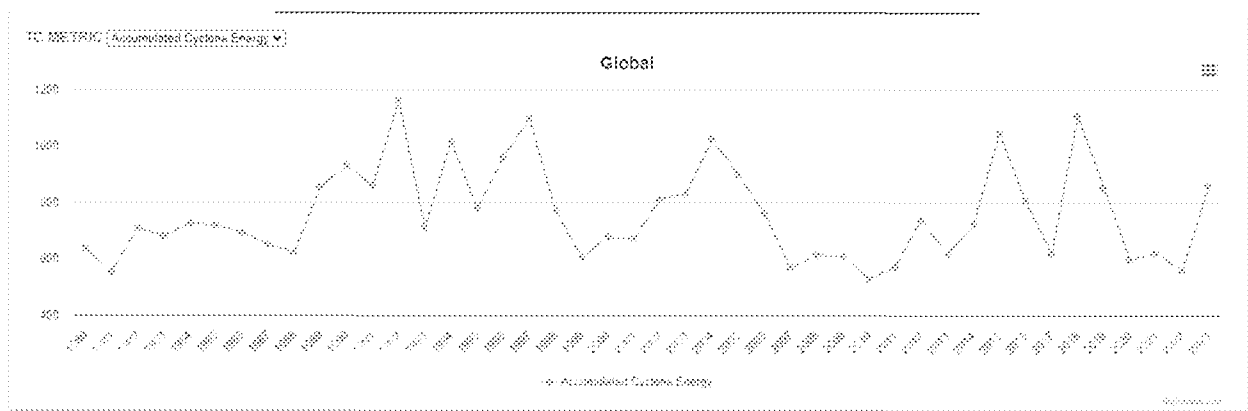


Figure 8.3.3: Global Accumulated Cyclone Energy. Source: Klotzbach (2025)
<https://tropical.atmos.colostate.edu/Realtime/index.php?arch&loc=global>

Note that Tu et al. (2024) report that the Power Dissipation Index (PDI), another different measure that combines hurricane number, duration, and strength, has either remained unchanged or has declined in all global oceanic basins since the mid-1990s.

Today's global climate simulations are too coarse to project changes in TCs directly. Rather, projections are derived from finer “downscaled” simulations or proxies involving sea surface temperatures, winds, and aerosols. By those methods, a warming climate is expected to show declining hurricane formation rates. (Chand et al. 2022). Climate models also project fewer Tropical Cyclones under future global warming, and even though models project they will increase in strength, the annual averages of rainfall maxima decline (Stansfield et al. 2020).

8.3.2 Wildfires

As shown in Figures 8.3.4 and 8.3.5 global wildfire activity as measured by European Space Agency peaked over a decade ago and shows a downward trend since.

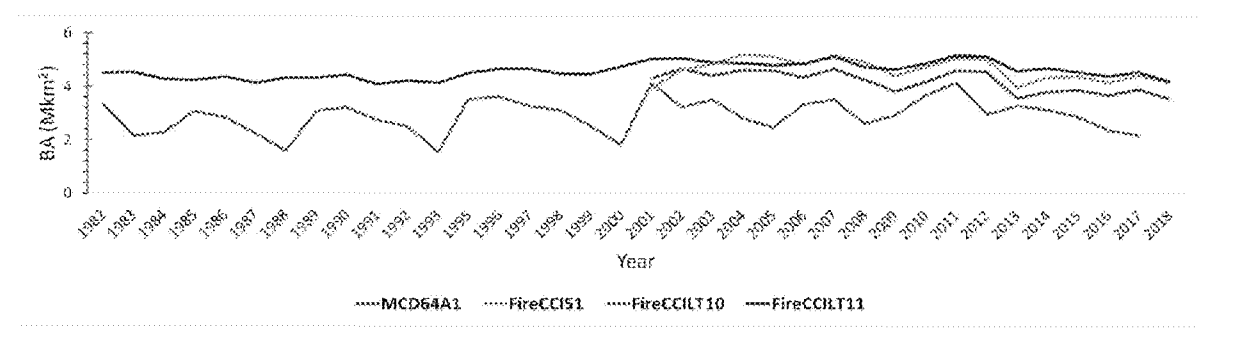


Figure 8.3.4: Global wildfire 1982-2018. Source: Copied from Oton et al. (2021). Note: the different coloured lines represent different data products based on satellites and algorithms used.

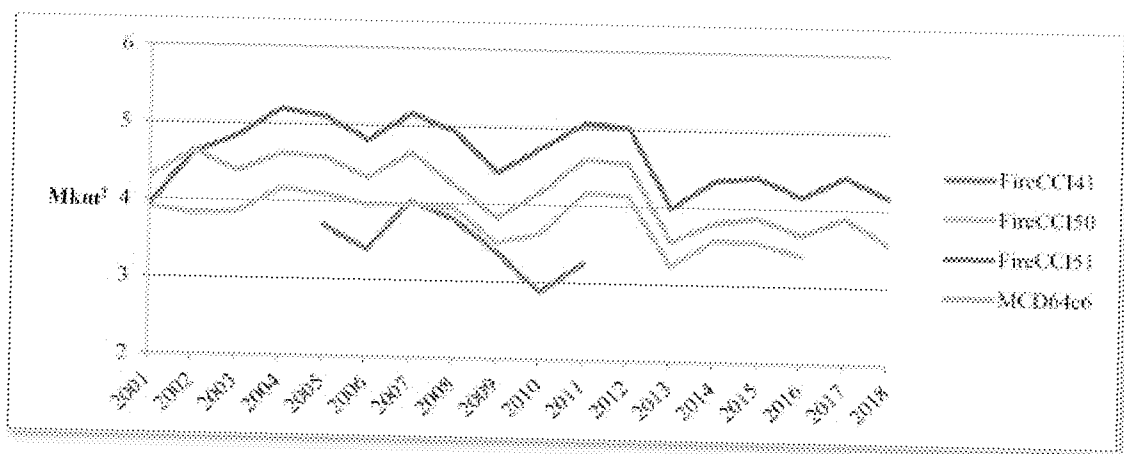


Figure 8.3.5: Global wildfire 2001-2018. Source: Copied from Lizundia-Loiola et al. (2021). Note: the different coloured lines represent different data products based on satellites and algorithms used

US data from the National Interagency Fire Centre (NIFC) from 1926 to 2023 are shown in Figure 8.3.6.

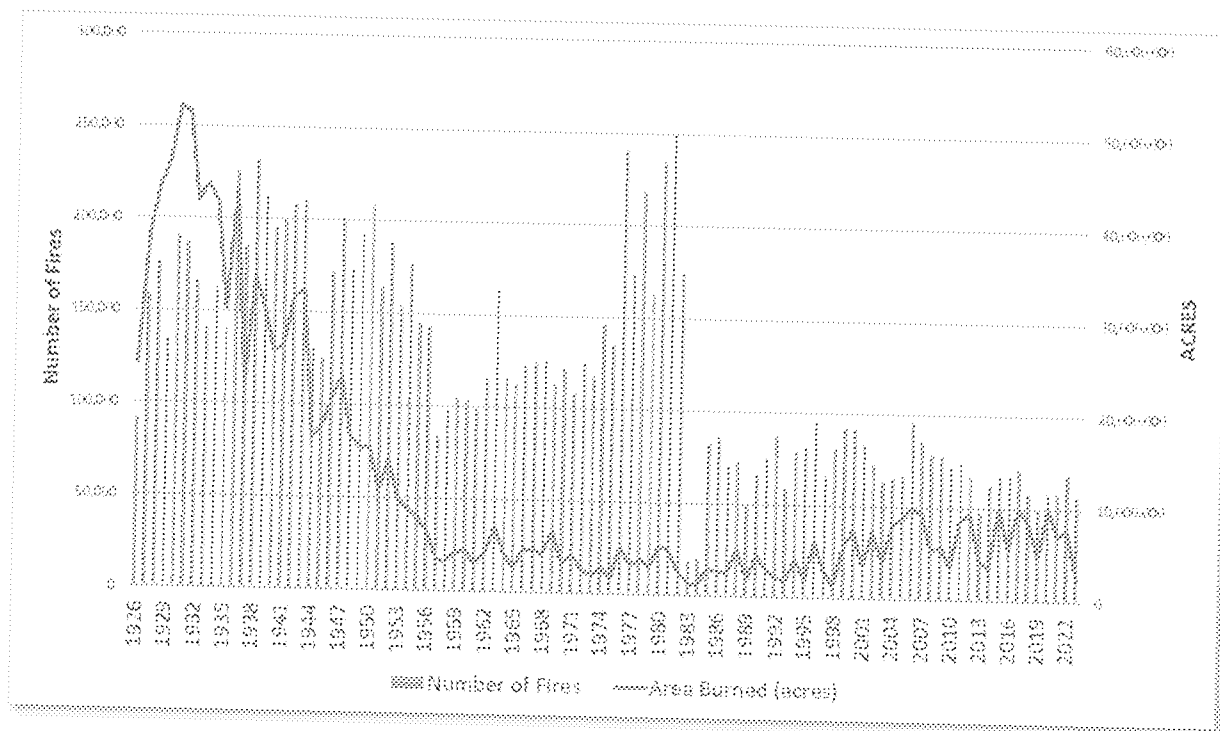


Figure 8.3.6: US wildfires 1926 to 2023. Source: National InterAgency Fire Centre data Pre-2017 (archived)

[https://web.archive.org/web/20200212033452/https://www.nifc.gov/fireInfo/fireInfo stats totalFires.html](https://web.archive.org/web/20200212033452/https://www.nifc.gov/fireInfo/fireInfo%20stats%20totalFires.html). 2018-2023: <https://www.nifc.gov/fire-information/statistics/wildfires>

Note the NIFC has removed the pre-1960 data from its current website. They claim it is because measurement methods changed after 1960. This explanation seems inadequate since agencies blend

temperature and extreme weather data series in other contexts when measurement systems changed. In this case if anything the measurement of wildfires has improved since the early 20th century so any bias will be towards understating early wildfire counts. Nonetheless just focusing on the post-1985 interval the number of fires is not increasing. The area burned did increase but only until about 2007.

It is difficult to establish a natural baseline for wildfire activity because of active fire suppression activity since 1900. Paleoclimatic evidence indicates, however, that past wildfire activity was much higher than at present. Marlon et al. (2012) used sedimentary charcoal layers to reconstruct fire history of western US for the past 1400 years. They also fit a model to predict expected fire activity as a function of climatic conditions. The results are summarized in Figure 8.3.7 below (from Figure 2 in their paper).

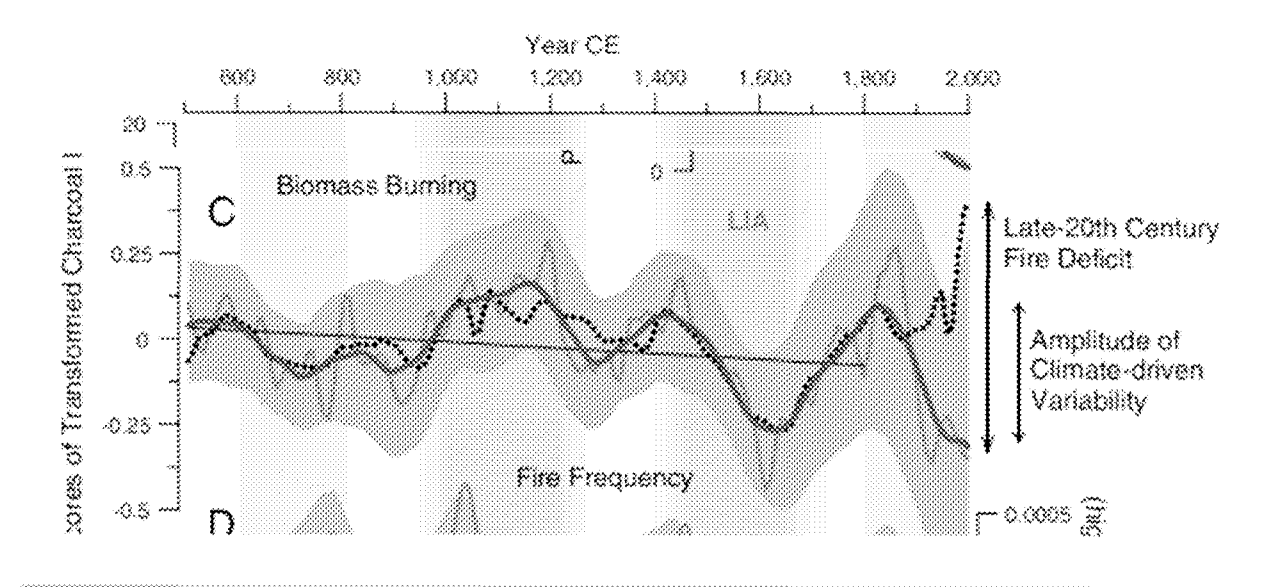


Figure 8.3.7: Fire frequency and fire deficit in the US. Source: Copied from Marlon et al. (2012)

In their figure the red line shows the smoothed charcoal record and the black dotted line shows the predicted charcoal record based on the statistical model. The gap at the end implies there has been a growing wildfire deficit over the 20th century. In other words, however much fire was observed in the 20th century it was less than what would have been observed in previous centuries based on the climatic conditions. Parks et al. (2025) likewise find that despite the recent increase in wildfire burn area in North America, a significant wildfire deficit remains relative to historical wildfire regimes.

8.3.3 Precipitation

Figure 8.3.8 shows that US long term data from NOAA shows an insignificantly increasing tendency toward extreme wetness (+0.001% per year)

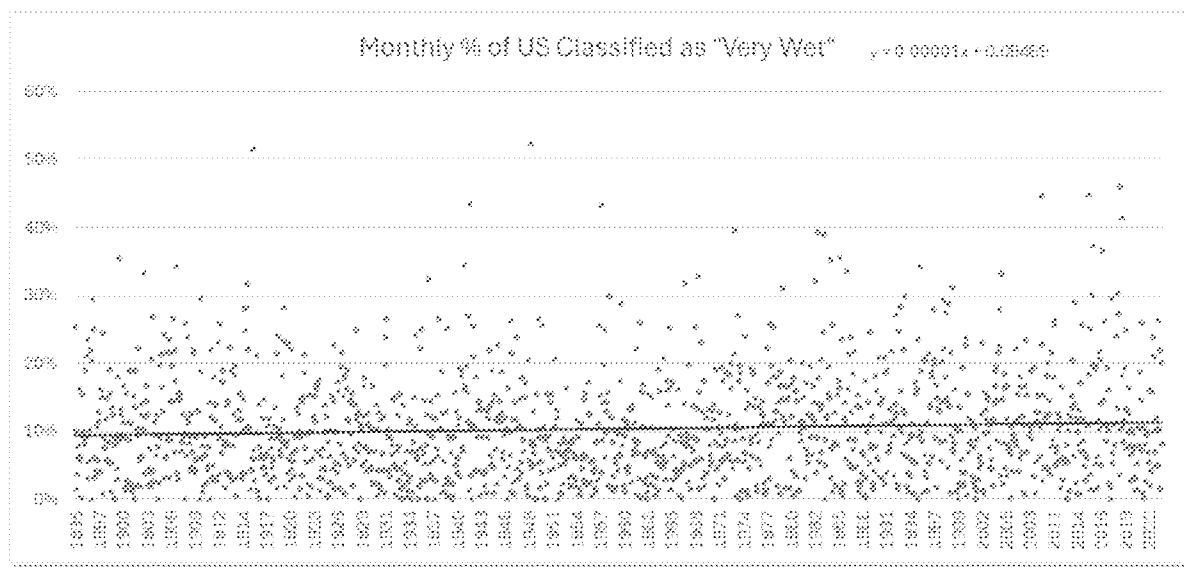


Figure 8.3.8: Long term US wetness (%). Source: NOAA
<https://www.ncei.noaa.gov/access/monitoring/uspa/wet-dry/0>

Precipitation will be discussed further in the review of CONUS data below.

8.3.4 Drought

As shown in Figure 8.3.9 US long term data (NOAA) shows an insignificantly declining tendency toward extreme dryness (-0.001% per year)

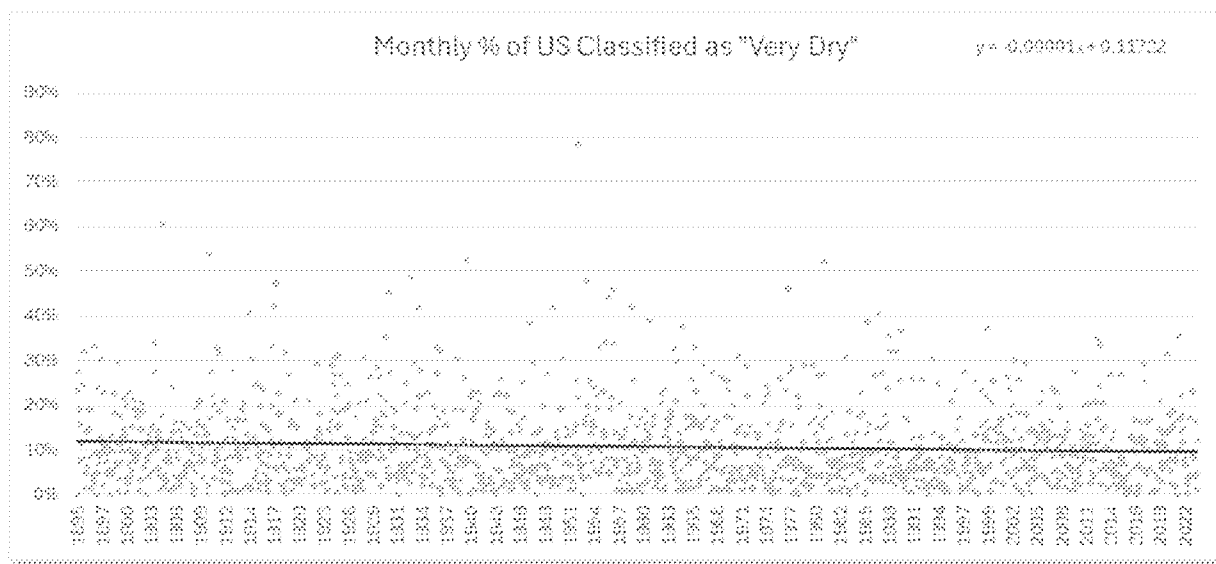


Figure 8.3.9: US dryness (%) 1895—2023. Source: NOAA
<https://www.ncei.noaa.gov/access/monitoring/uspa/wet-dry/0>

Kogan et al. (2020) examines a 38-year high-resolution satellite-based drought measure and concludes that global drought has not intensified and is not connected to climate change: “it is possible to state firmly that global and main grain countries’ drought area and intensity trends have not been following global climate warming since 1980’s.”

8.4 Temperature and precipitation extremes in the Contiguous US (CONUS)

8.4.1 CONUS daily temperatures are becoming less extreme

Daily maximum temperatures in the warm season (TMax, May-Sep) and daily minimum temperatures in the cold season (TMin, Dec-Mar) are available beginning in Dec 1898 (126 years). The dataset consists of 1,211 CONUS stations designated as United States Historical Climate Network or USHCN stations (Quinlan et al. 1987, Karl et al. 1990). These stations were selected by NOAA as having the fewest problematic issues with gaps, station moves and instrument changes. Where gaps still exist, nearby stations (bias-corrected) were merged so that the median volume of data available for a station is 98%. Although there are certainly errors in the dataset, with over 1,000 stations we can have relatively high confidence in any underlying signal that might be discovered.

We begin with the question of whether the occurrence of daily record high or low temperatures changed has changed since Dec 1898. Each warm-season has 153 days (1 May to 30 Sep) and each cold-season has 122 days (1 Dec to 31 Mar). For each station and day, we calculated the year in which the record highest (lowest) temperature occurred. With 126 years of observations, if there were no temperature trends over time, the expected number of records for TMax would be 1.21 ($=153/126$) per station per year and for TMin 0.96 ($=122/126$) per station per year. Figure 8.4.1 indicates the observed distribution in time of the occurrence of these extreme events.

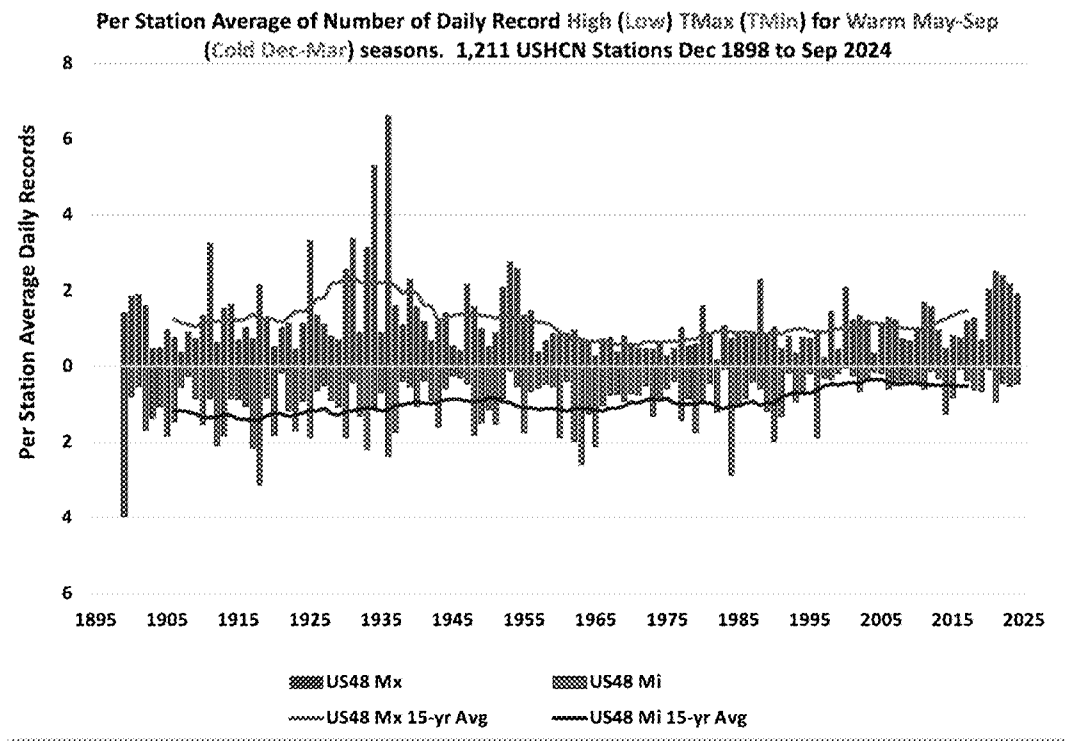


Figure 8.4.1 Number of daily record High (red) and Low (blue) for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92% of observations in the 126-year period since Dec 1898.

The results indicate a common feature in many metrics of warm-season extremes in the CONUS - the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. On a per-station average, 60% of the TMax records and 59% of the TMin records occurred in the first half of the period (1899-1961).

On the cold side, the Valentine's Day Arctic outbreak in Feb 1899 stands as the most extensive cold extreme experienced by the CONUS, with 1917 2nd. The frequency of cold records has declined, especially over the last quarter of the period in which only 13% of the extreme cold events were measured. In contrast, 25% of the extreme TMax records were achieved in the last quarter in accordance with statistical expectations. These general features have been noted in past assessments (IPCC AR5, IPCC AR6, NCA4, NCA5). Combining the two records the overall reduction in numbers of both cold and hot extremes over the past century indicates a climate less prone to extremes.

This pattern is also shown in Figure 8.4.2. For each station and for each year the hottest warm season and coldest cold-season temperatures were calculated and converted to anomalies relative to the station's long term warm and cold season (respectively) averages. Then the differences between these were computed by station and geographically-averaged over all stations, thus yielding an annual measure of the expected range of local extreme temperatures for each year. Figure 8.11 shows the 15-year trailing average of this measure which has clearly declined over the past century.

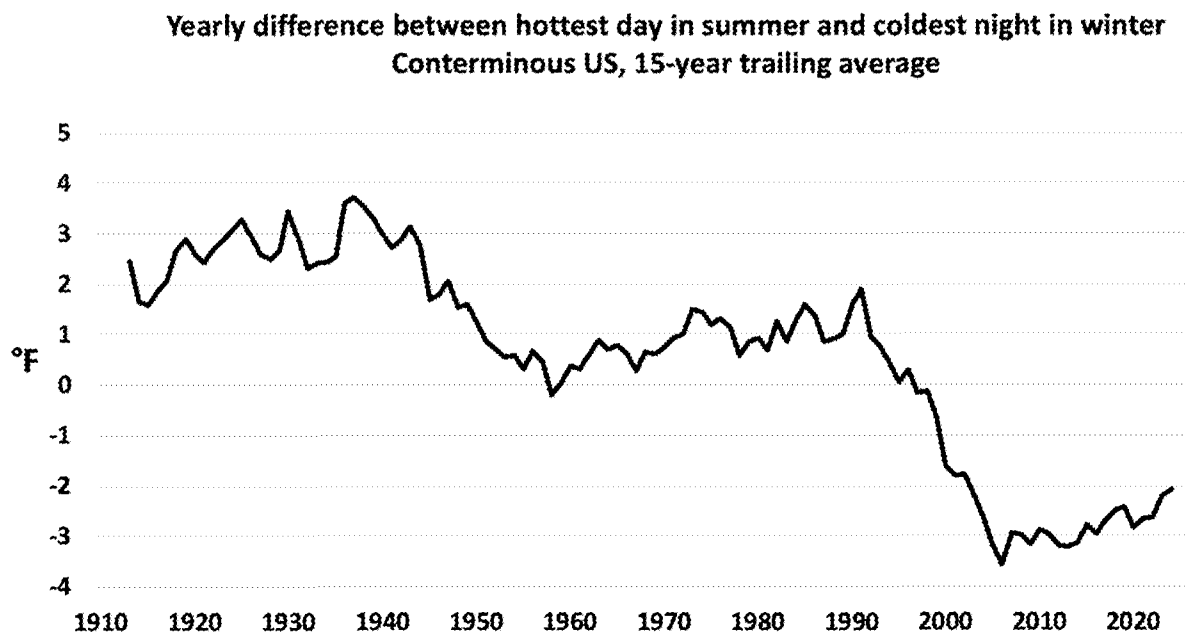


Figure 8.4.2. 15-year trailing average of the difference each year of each station's hottest warm-season TMax and coldest cold-season TMin relative to the long-term average.

The average difference for each station between the hottest summer TMax and coldest winter TMin has declined about 5°F in the past 126 years. The decline is due mostly to warming winter TMin, but a decline in the magnitude of summer TMax is also a factor. The rise in TMin has been strongly related to the growing presence of manufactured surfaces around the weather stations over the last 100+ years (Spencer et al. 2025).

Summarizing Figures 8.4.1 and 8.4.2, while temperature extremes are regularly experienced in the US and attract a great deal of media attention, long term records show the US climate has become less extreme over time (milder) when measured in terms of the range between warm season maxima and cold season minima.

8.4.2 Exceedances of a heat threshold

Under the heading of “The Risk of Temperature Extremes is Changing”, the most recent US National Climate Assessment report (NCA5) notes the increase in a threshold metric of number of days at or above 95°F, stating,

“The western US has been particularly affected by extreme heat since the 1980s ..., experiencing a larger increase in days over 95°F, as would be expected given the greater warming in that region relative to the eastern US. Several major heatwaves have affected the US since 2018, including a record-shattering event in the Pacific Northwest in 2021.”

Are the occurrences of 95°F days changing? In a climate as varied as that of CONUS, threshold statistics can be misleading. A region with many stations that have near 95°F TMax average temperatures in the summer might see large swings in the metric when only small changes in average temperature occur. Elsewhere with stations that either rarely or virtually always achieve 95°F TMax temperatures, a small change will not impact the results much at all. In the past 126 years, the average CONUS station experienced 129 days exceeding 95°C per 6-yr period, but the regional values range from 278 in the Southern Plains to 9 in the Northeast. Thus, one needs to view such threshold analyses with caution.

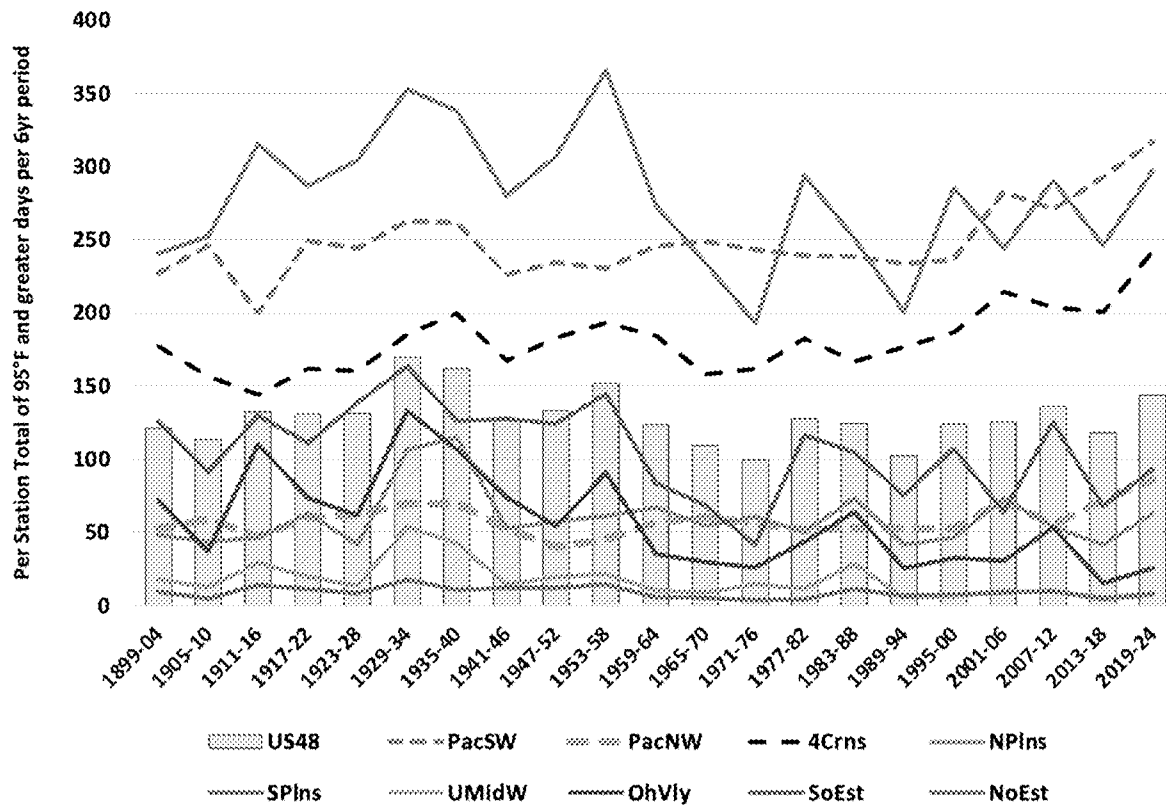


Figure 8.4.3. Total number of days $\geq 95^{\circ}\text{F}$ in 6-yr periods, US 48 (bars) and regions (lines).

In Fig. 8.4.3 we see that only three of the nine regions, all in the West, have experienced upward trends in the number of 95°F or hotter days (dashed lines). The CONUS as a whole has not and the other six regions have experienced declines.

The Pacific NW heatwave of 2021 is referenced as of the NCA5 claim, an event we examine more closely in Section 6.4. The evidence indicates it was a “black swan” event; *i.e.*, a single, unprecedented event in the record, not part of a pattern of increasing extreme heat. For example, the 5-day average tropospheric grid-point temperature anomaly over the Pacific NW during that event was $+10.8^{\circ}\text{C}$, the most extreme NH grid point summer anomaly in the 46 years from over 4 million grids. In contrast, the global anomaly during that time was virtually zero ($+0.03^{\circ}\text{C}$, Mass et al. 2024).

The heading “The Risk of Temperature Extremes is Changing” suggests positive trends are now being observed in threshold temperatures on a widespread basis, but that is not evidenced in the combined CONUS results of the figures above.

8.4.3 Heatwaves

Heatwaves (consecutive days that exceed an extreme threshold) have a greater societal impact than a single daily record. We measure “Heatwave Days” here as the count of all days in May-Sep each year that exceed the 90th percentile and that lie within a run of at least six consecutive days. This is equivalent to the method used in NCA5 except that the reference period here is the entire record 1899-2024 while NCA5 truncated the reference period to 1961-1990, a cool time. That truncation

boosts positive results (days exceeding the 90th percentile) in periods warmer than the reference period, especially starting in 1960 and moving to the present (see *Urban Influences* below).

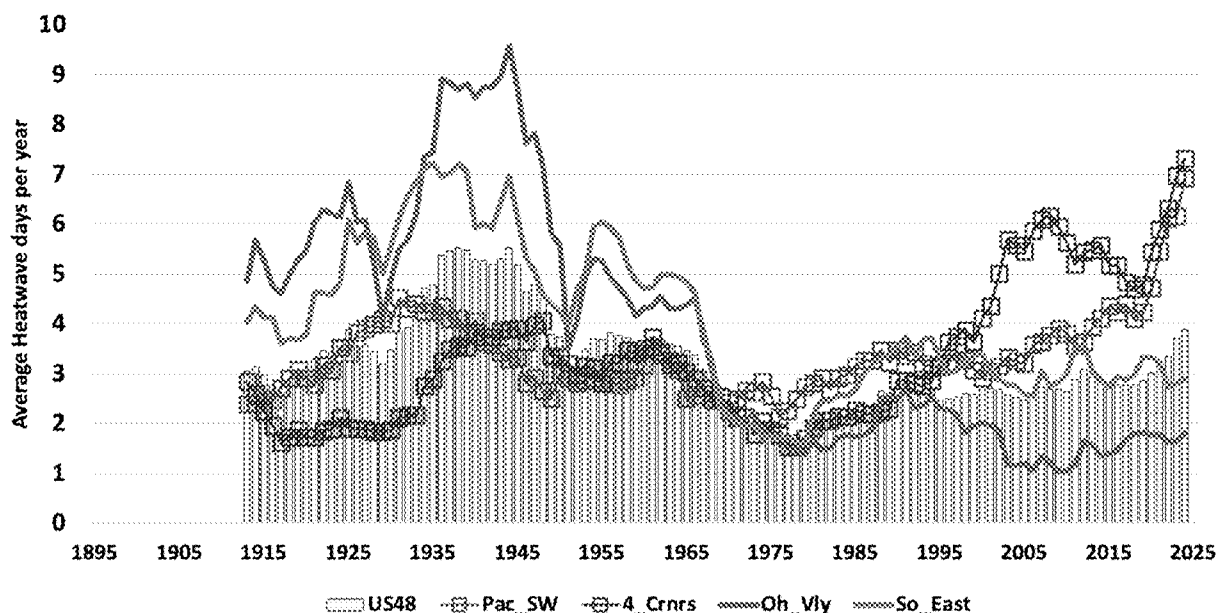


Figure 8.4.4 15-year trailing average of number of heatwave days per year per station in the CONUS (bars) and four regions: Pac_SW (purple squares, CA, NV), 4_Crnrs (red squares, AZ,NM,UT,CO), Oh_Vly (blue, MO, IL, KY, TN, IN, OH, WV) and So_East (green, MS, AL, GA, FL, SC, NC, VA).

Figure 8.4.4 indicates again the excessive heat of the first half of the 20th century, primarily in the eastern two-thirds of the nation, as seen in the regional values for the Ohio Valley and the Southeast as examples. The West has seen a recent increase of heatwave days and the two regions with the highest number are shown, the Pacific Southwest and the Four-Corners (NCA5). This indicates that the background warm season circulation favored heatwaves in the eastern portions of the country in the first half of the 20th century, but in the 21st century the patterns have favored heatwaves in the West. For CONUS as a whole, heatwaves are no more common today than they were a century ago.

Of interest here is the regional variation of this metric. The four northern regions (Pacific NW, Northern Plains, Upper Midwest, and Northeast) on average experience 15 to 27 heatwave days per 15-year period. In contrast, the five southern regions (Pacific Southwest, 4-Corners, Southern Plains, Ohio Valley and Southeast) see 37 to 54 such days, essentially twice as many. This suggests the summer circulation pattern is more prone to stationary events in the southern regions while transient systems in the northern regions are more common and thus cut short these potentially longer events.

Urban influences

The NCA5 directs readers to the website <https://www.globalchange.gov/indicators/heat-waves> (USGCRP 2023) to view the number of urban heatwaves by decade from the 1960s. The figure shows a monotonic increase in each decade from 2 occurrences per year in the 1960s to 6 in the 2020s. The definition of a heatwave is an unusual but practical measure of human discomfort - a period of at

least 2 consecutive days when the minimum apparent temperature (combination of temperature and humidity) exceeds the 85th percentile. Note too, the dataset is limited to the 50 largest U.S. cities.

These increasing values since 1960 presented in USGCRP (2023) are entirely reasonable, but are unrelated to GHG emissions for at least two reasons. Urbanization in these cities is a major factor in the rise of TMin relative to co-located TMax and relative to TMin at rural stations. Also, the 1960s was the coldest decade and 1970s the second coldest decade since the 1910's, so this starting date preconditions the time series to show increases. This does not dismiss the real rise in nighttime temperatures in major U. S. cities and the societal impacts associated with these changes. However, we note for a variety of reasons, that summer TMax (especially in rural areas) serves as better response variable for detecting potential changes in heatwaves influenced by changes in the background climate due, for example, to increasing GHGs (Christy et al. 2009). For the CONUS as a whole, the evidence in this section suggests GHG emissions have had little-to-no effect on heatwaves.

8.4.4 Extremes in daily precipitation.

Because precipitation involves a discrete phase change (water vapor to liquid), it is stochastic and episodic in character and requires careful statistical treatment to understand variability over long time periods (see *8.1 Introduction*). The US National Climate Assessments (NCA4, NCA5) have highlighted an increase in the occurrence of the heaviest precipitation events (defined in different ways) primarily in the eastern half of the CONUS, especially the Northeast, when starting in either 1901 or 1958. Interestingly, the regional variations indicate that the largest increases in extreme events are in the Northeast and the smallest in the West, a trend counter to the changes in temperature extremes.

McKittrick and Christy (2019) examined long-term and consistent station observations of daily precipitation to test some of these NCA claims for the Southeast and West Coast. When the time series were extended back in time (as far as 1872 in some cases) or when starting later (1978), there were no significant trends for either region. For this report we updated these findings with similarly constructed observations from 29 stations on the Pacific Coast (1893ff from San Diego CA to Blaine WA), 24 stations in the humid Southeast (1872ff from Austin TX to Washington DC), and 21 stations in the Northeast (1888ff from Buffalo NY to Gardiner ME). The results were as follows.

Pacific region:

- Average precipitation trend is significant (downwards) in Astoria, insignificant elsewhere.
- The trend in rainfall variance is positive and significant in Big Sur, insignificant elsewhere.
- The trend in daily maximum precipitation is positive and significant in Aberdeen and Big Sur and negative and significant in Newport (insignificant elsewhere).
- Averaged over all stations in the region none of these three trend parameters is statistically significant.

Southeast region:

- The trend in average precipitation is positive and significant in Mobile and Quitman, insignificant elsewhere.
- The trend in rainfall variance is positive and significant in Mobile, insignificant elsewhere.
- The trend in daily maximum precipitation is positive and significant in Vicksburg and Norfolk, insignificant elsewhere.
- Averaged over all stations in the region none of these three trend parameters is statistically significant

Northeast region:

- The trend in average precipitation is positive and significant in 9 of 21 locations and in the region averaged overall.
- The trend in rainfall variance is positive and significant in Portland, Albany and Buffalo, insignificant elsewhere.
- The trend in daily maximum precipitation is positive and significant in Portland and Gardiner, insignificant elsewhere.
- Averaged over all stations in the region the trend parameters for variance and maximum precipitation are not statistically significant.

Pacific Coast heavy rainfall events

The Pacific Coast receives considerable precipitation from Atmospheric River (AR) events which often last more than a day or two (e.g., Gershunov et al. 2017, Pan et al. 2024). The worst-known such event in recent history was the ArkStorm that occurred between December 1861 and January 1862, which dumped nearly 10 feet of rain in parts of California and submerged the entire Central Valley for weeks under as much as 15 feet of water (Brewer 1930, Null and Hulbert 2007). Paleoclimate research has found six megastorms more severe than 1861–1862 in California during the last 1800 years, occurring at intervals of 300 years or so (Porter et al. 2011).

SIDEBAR: Perils of short data records

San Francisco provides a good case study of the limitation of using short historical samples to characterize natural variability of extreme events. Suppose we use a 130-year sample of daily San Francisco precipitation from 1895 to 2024 and we look for 3-day, 5-day, 14-day and 30-day rainfall records. The results are as shown in Table 8.2.

Event	Record (inches)	Year
3-day	6.94	2023
5-day	8.55	2023
14-day	12.62	2023
30-day	18.93	1998

Table 8.2: Extreme rainfall records, San Francisco, 1895-2024.

The records all cluster in the more recent data. 2023 appears to be an exceptional year and since it is near the end of the sample it might suggest that the climate has shifted into a more hazardous state, perhaps as a result of human influences.

But the picture is very different if we use a sample that begins 45 years earlier, in 1850. Table 8.3 shows that the record-setting events then all happened in the 1860s. Furthermore 2023 is now not even in 2nd place but falls to 3rd or 4th. Also, comparing the records of the two charts the extreme precipitation events in 1862 and 1867 involved considerably more rainfall than the 1998 and 2023 events, with 14- and 30-day totals about 50 percent higher.

Event	Record (inches)	Year	Rank of 130-yr extreme
3-day	8.85	1867	3
5-day	9.80	1867	3

14-day	19.05	1862	4
30-day	28.25	1862	2

Table 8.3: Extreme rainfall records, San Francisco, 1850-2024.

The range of natural variability is made even more remarkable when paleoclimate evidence is examined. Porter et al. (2011) discovered that in the past 1,800 years at least six megastorms were more intense than the devastating 1861-62 ArkStorm that struck the region. Evidently such extreme events have impacted the region about every 300 years, though not since 1895.

This example illustrates the limitations of using relatively short climate periods (~130 years) to assess the character and range of natural variability in general and of extreme events in particular. Accurate representation of the full range of natural variability is necessary for any attribution analyses (see 6.4). Infrastructure planners, emergency management institutions and attribution scientists would understand the significant mischaracterization of the magnitude of a future extreme if based only on the last 130 years. In this case, a single time-sample of 130 years provides an underestimation of the extreme value by up to 50% determined when adding only 45 more years of observations. Compared to millennial-scale paleoclimate evidence, an even greater underestimation would occur. An important lesson is that the climate can deliver great surprises on its own, even without human influences.

We examine occurrences of 5-day deluges as follows. In a 130-year span there are 26 5-year intervals. At each location we computed the 5-day precipitation totals throughout the year and selected the 26 highest values. A single year may have more than one of the 26 heaviest. Each of those can be thought of as 1-in-5yr events. If there are no trends in precipitation then the total number of these events across all stations should be evenly spread out over the years. In Fig. 8.4.5 we show the distribution in time of these events. The deluges associated with the massive 1997-98 El Niño event are readily apparent. While erratic, as is typical of these types of precipitation metrics, there is no indication of a tendency to become more frequent over time.

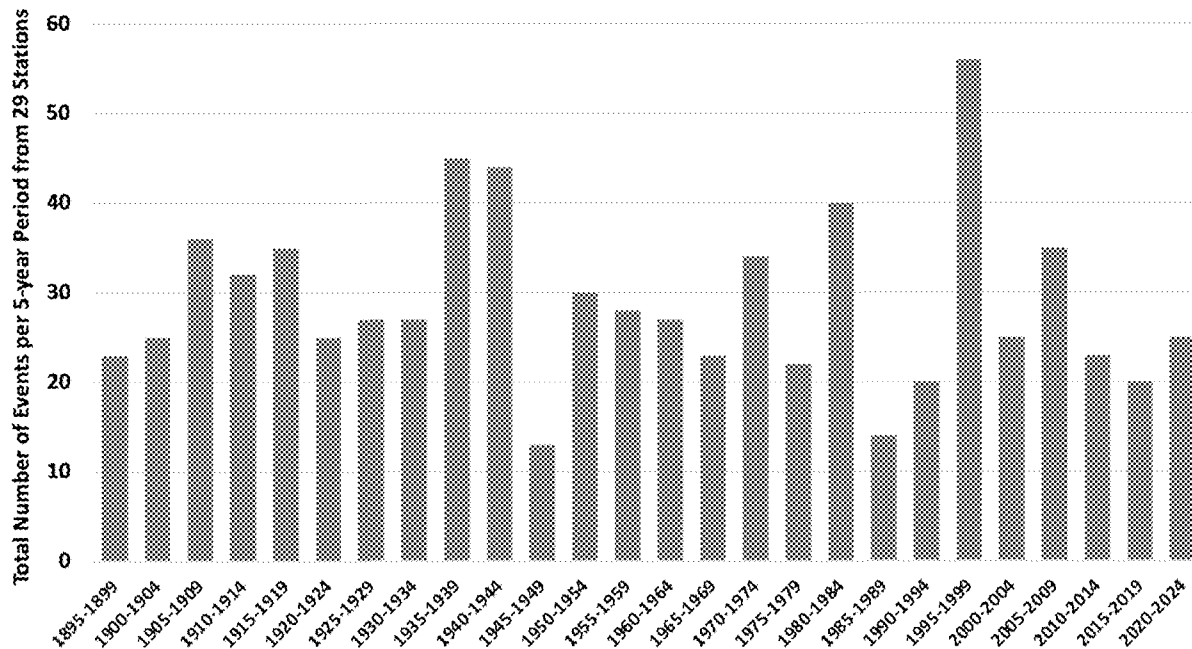


Figure 8.4.5. The time distribution by 5-year periods of the 26 heaviest occurrences for each station (i.e., nominal 1-in-5 year event).

Southeast heavy rainfall events

The temporal pattern of 5-day totals of the 1-in-5yr heavy events in the humid Southeast (Figure 8.4.6) is generally unremarkable, though a cluster of higher values appears in 1995 to 2019. The increase in those years is due largely to the 4 northeastern-most stations of Wilmington NC, Weldon NC, Washington DC, and Norfolk VA. This confirms the pattern indicated in NCA4 and NCA5 of a tendency for an increasing frequency of heavy events, due to a temporal clustering of tropical storms from eastern NC to Maine discussed below. Otherwise, the remaining 20 stations show an unremarkable temporal distribution of heavy events.

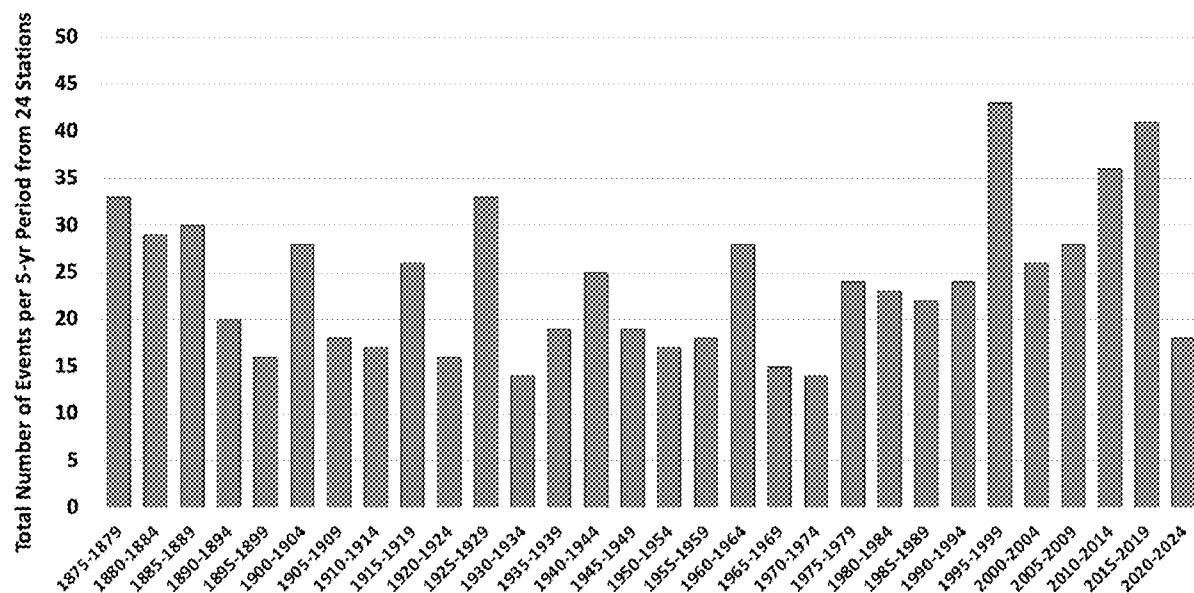


Figure 8.4.6. As above but for the 30 heaviest 1-in-5yr events for 24 stations in the humid Southeast from Austin TX to Washington DC in 5-year bins for 1875-2024.

Northwest heavy rainfall events

Fig. 8.4.7 shows the 27 (1-in-5yr) heaviest 3-day events for the last 135 years in 21 stations in the Northeast (including Montreal Canada). We use 3-day totals here as this produced the largest variations in time. In this region, 72% of the events occur during June to October and are dominated by tropical incursions of hurricanes, tropical storms or tropical storms that transition to extratropical systems. According to NCA4 and NCA5 this region experienced the largest increases in extreme events, so it shall be examined more closely.

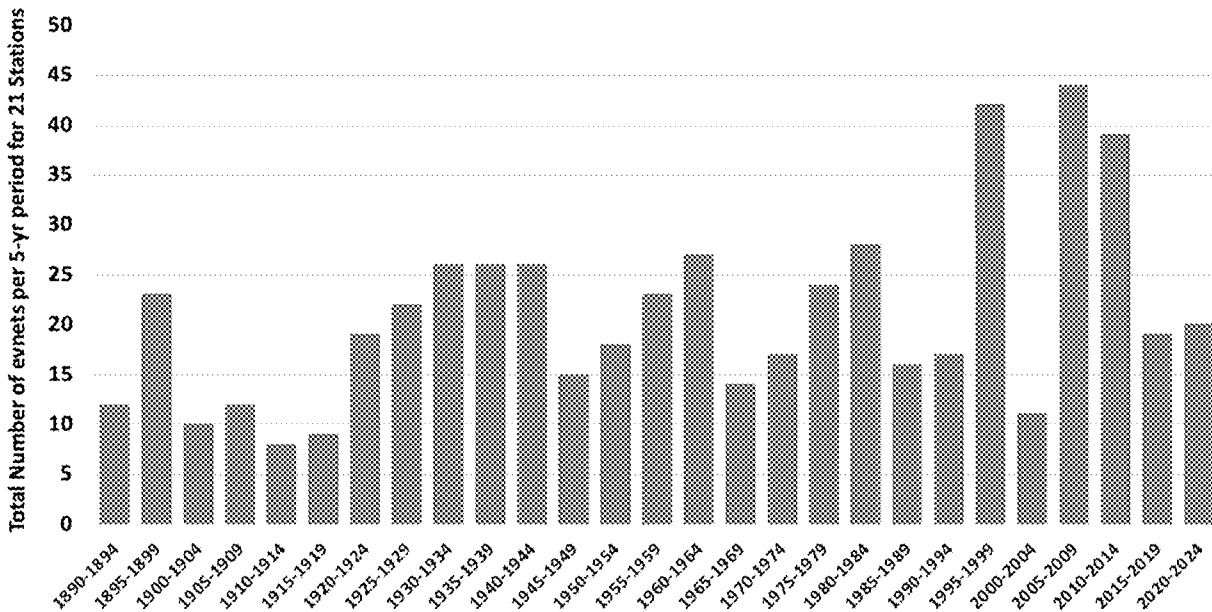


Figure 8.4.7. Time distribution of the heaviest 27 (1-in-5yr) heaviest 3-day precipitation events for 21 stations from NY to ME, including Montreal.

Howarth et al. (2019) report differences in the Northeast between two 18-year periods: 1979-96 and 1997-2014 (a similar region as in Fig. 8.16 that includes PA and NJ) of various precipitation extremes. One metric which indicated a dramatic increase (317%) was found for 24-hr events > 6 inches. This high increase is due to the very small numbers of such events of which there were only 6 in the first period and 25 in the second as reported for 58 stations. This high percentage increase is due to the very small numbers of the events; only 6 in the first period and 25 in the second. Most of the stations, did not record such an event suggesting these erratic, episodic events over brief, 18-yr periods, need scrutiny by additional statistical methods.

Using the information in Fig. 8.4.7 over the same years as Howarth et al. we find a 51% increase in the frequency of heavy events between the two periods. One can see in Fig. 8.16 that it was unfortunate that Howarth et al. ended in 2014 prior to a return to the long-term average of such events.

A feature of Howarth et al. is the use of single day totals which is questionable because extreme events are often spread across the time-of-observation boundary. Thus stations measuring at 0700 LT versus those at Midnight will have differing results for a particular event which would then have major impacts on counting these events. We use the 3-day totals in Fig. 8.4.7 to be sure to capture the extent of these extreme downpours. In any case, we can confirm that the period 1997 to 2014 experienced a cluster of heavier events as Howarth et al. have documented.

Howarth's most remarkable claim (317% increase in 6" days) is potentially misleading because it is a threshold statistic (see Section 8.4.2 above) and a ratio of small numbers over a short period. The result is not representative of *relative* extreme events for the whole region since the majority of stations never experienced a 6" total. Fig. 8.16 above determines the same number of events for each station (27 heaviest events) whose heaviest values ranged from 4.4" to 12.5" and their 27th heaviest values ranged from 3.3" to 5.0". This analysis thus allows each station to be equally represented. In

other words, if there is a region-wide increase in heavy events, it should be seen in the sum of all stations. Note too that the period of record here is 135 years vs. 36 years of Howarth et al. Except for three 5-year periods between 1995 and 2014 there is nothing statistically remarkable about the results in Fig. 8.4.7.

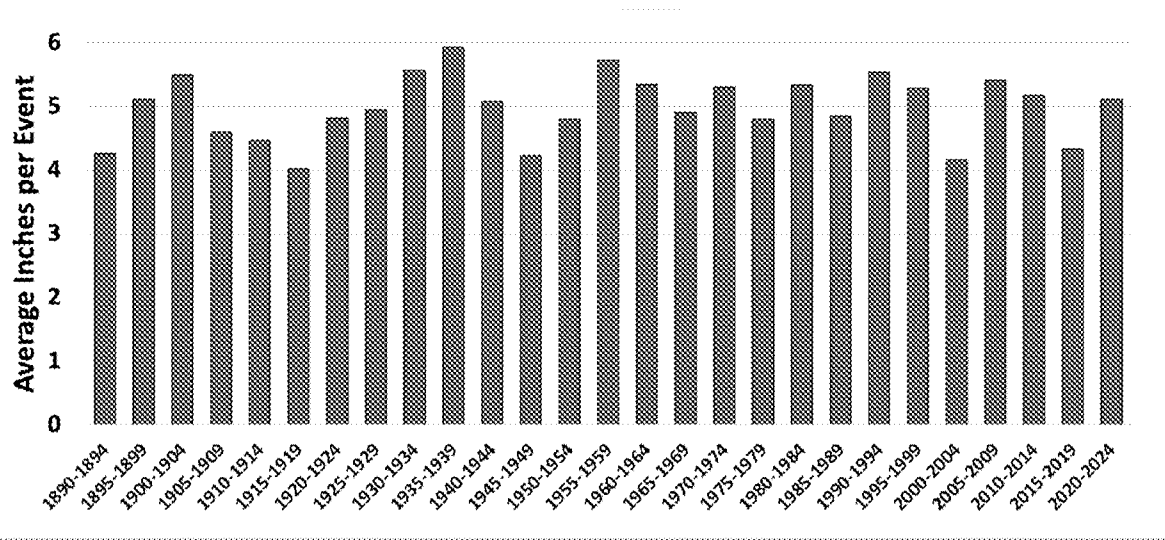


Figure 8.4.8. Average amount of precipitation falling in the 1-in-5yr events for the NE stations.

An interesting aspect of Northeast precipitation is that there has been no change in the amount of precipitation per heaviest event, as shown in Fig. 8.4.8. The trend is only $+0.02''/\text{decade}$. The highest amount, 1935-39, includes the Great New England Hurricane of 1938, one of the rare major (Category 3 or higher) hurricanes to strike the region. The results in Figs. 8.4.6 and 8.4.7 suggest that though there was an uptick in the number of events during the period 1995 to 2014; the events, individually, are not becoming more intense.

Jong et al. (2024) document the increase of tropical influences on precipitation events in the Northeast since 1959 and concluded, “The autumn extreme precipitation trend over the Northeast US is primarily attributed to tropical cyclone-related events since the 1990s.” The question then becomes, was the temporal clustering of tropical systems in 1997-2014 which affected the Northeast a response to increasing GHGs? Jong et al. examined CMIP-6 model output which suggests that there will be fewer such systems in the 21st century but that the intensity of the rainfall events might increase. This conjecture is not seen in Fig. 8.17 where the amount-per-event has remained steady over the 135-year period.

For substantial urban areas there is some evidence to indicate the heaviest rainfall events may be redistributed due to the impact urban infrastructure has on the local weather (e.g., Pielke Sr. et al. 2011, Zhang et al. 2018, Yang et al. 2024). Yang et al. state, “Cities that experience compact development tend to witness larger increases in extreme rainfall frequency over downtown than their rural surroundings, while the anomalies in extreme rainfall frequency diminish for cities with

dispersed development.” While this is an important insight to consider, the effect on the specific stations used in this analysis is unknown, or at least not detectable in Fig. 8.17.

In summary, the evidence from the historical record of extreme precipitation events in the CONUS is generally not consistent from region to region so that inferences regarding trends and their projections are wrought with significant uncertainty. In most regions and perhaps all, it is our opinion that the very nature of the erratic and episodic character of extreme precipitation events renders the discovery of statistically significant changes, including a relationship to CO₂ concentrations, a result yet to be achieved (McKittrick and Christy 2019).

8.5 Summary

Based on the content provided in the document, here are the five most important takeaways:

1. Limited Detection of Anthropogenic Signals: The IPCC has asserted high confidence in detecting an anthropogenic signal in only 4 out of 34 weather impact categories, and medium confidence in 4 more. For the remaining 26 categories, no anthropogenic signal is claimed to be detected.
2. Slow Emergence of Trends: Even under the most extreme forcing scenario (RCP8.5), the IPCC expects very few anthropogenic trends to emerge within this century for most weather impacts.
3. Natural Variability Dominance: Natural variability continues to dominate patterns of extreme weather systems. Simple assertions of trend detection are often complicated by regional heterogeneity and trend reversals over time.
4. RCP8.5 Scenario Implausibility: The document notes that the RCP8.5 scenario is described as an implausible high-end storyline, not a "base case" or "business-as-usual" projection.
5. Conflicting Messages on Attribution: The document mentions that AR6 (IPCC Sixth Assessment Report) offers conflicting messages about the attribution of extreme weather to anthropogenic causes, highlighting the complexity and uncertainty in this area of climate science.

These takeaways emphasize the nuanced and complex nature of attributing extreme weather events to climate change, and the importance of considering natural variability and uncertainty in climate projections.

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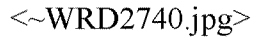
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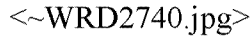
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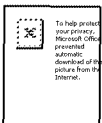
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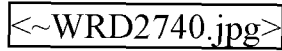
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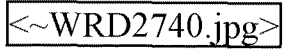
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On Tue, May 6, 2025 at 12:12 PM John Christy <climateman60@gmail.com> wrote:

All

We can fill in without much trouble the change, or lack thereof, of "high impact" weather events (mainly wind and flooding like hurricanes, tornadoes etc) in the CONUS Extreme chapter. The temp and precip metrics are important because they are just long enough to essentially tell us Mother Nature has a mind of her own.

1. I'll look at Ross's version of 8 soon, but my hope was that Ross would translate the statistical remarks into the correct language(eg are their more precise words that chaotic, episodic, stochastic, etc).

2. We have analyses of the CONUS with more complete datasets than the NCA used (recall NCA analyses depended essentially on a small group at NCEI using datasets that (a) were not very consistent in time, (b) could promote alarm and (c) already easy for them to get to. Our datasets have literally hundreds of thousands of manually keyed-in observations for temporal consistency. In other words, this lets people know we can address these issues from soup to nuts - we're not armchair climate scientists ... we can reproduce what they did, but make the analysis more comprehensive to address the questions.

John C.

Sent from my iPhone

On May 6, 2025, at 4:14 AM, Ross McKittrick

<ross.mckitrick@gmail.com> wrote:

Just read your attribution chapter. I hadn't picked up on the gap between IPCC Ch 11 vs Ch 12 language but i see your point that rather than promoting one set of attribution findings we should explain that even within the same AR different authors assessed things differently. One option is to leave Ch 6 where it is but reverse the order of Ch 7 and 8 while retitling the latter as you suggest. That way, having established the extreme weather types for which there are no detectable trends it will more naturally follow that they won't be discussed in the attribution chapter.

On Tue, May 6, 2025 at 9:45 AM Judith Curry <curry.judith@gmail.com> wrote:

Ok, but the summary table (12.12 from AR6) is inconsistent with conclusions in AR6 ch 11 (I point this out in section 6.4 of my attribution chapter).

In my mind, the main point is disagreement and ambiguity I would suggest chapter 8 going before chapter 6, retitling it as US Weather and Climate Extremes, and make it more of a data chapter, not an attribution chapter (I would put table 12.12 in the attribution chapter if you want to include the actual table)

On Tue, May 6, 2025 at 6:39 AM Ross McKittrick <ross.mckitrick@gmail.com> wrote:

I like john's material too which is why I included it and am working on the extended regional analyses. But on this topic people are heavily primed to believe that extreme weather of all kinds is getting worse due to climate change. The assertion shows up everywhere climate change is discussed including in academic papers. I think it is very valuable to show people that neither the IPCC nor the NCA support such this view. We should at least lead off with the summary table. The library of quotes can go to an appendix but I have

found in my public speaking that they have considerable persuasive force for most people. We also need to address floods, droughts, hurricane landfalls, tornadoes etc. I don't see any reason to delete all that material.

On Tue, May 6, 2025 at 9:22 AM Judith Curry <curry.judith@gmail.com> wrote:

I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes"

I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable severe weather event.

John's version meshes very well with my version of chapter 6. Read especially section 6.4 of my chapter. I note a discrepancy between chapters 11 and 12 in terms of detecting and attributing extreme events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the problems/challenges, and topics that are particularly relevant for the US

On Mon, May 5, 2025 at 7:47 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I have wrangled the extreme weather chapter into something I hope flows better and is more readable. I adopted Judy's editorial changes and then the new changes I made are in red. I added some new Figures showing results on PC and SE data and will add the NE chart when I get the data. I also made some labeling suggestions including for the 3 rainfall charts that are hard to understand. Section summaries and an overall summary are still needed.

Ross

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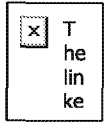
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8 Extreme weather in the US and elsewhere

8.1 Introduction

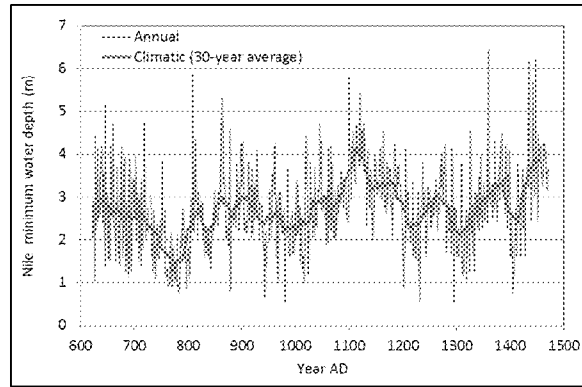
Weather extremes, usually related to temperature and/or precipitation, can disrupt infrastructure and therefore endanger human health and wellbeing. The issue is not whether extremes occur, for they are intrinsic to the chaotic climate system. Rather, it is whether there are long-term (decadal scale) changes in the frequency or character of extremes (“detection”), as well as the extent to which such changes and the attendant changes in hazards are caused by anthropogenic emissions of greenhouse gases (“attribution”; e.g., IPCC AR6 Seneviratne et al. 2021).

It is naïve to assume that any recent unprecedented extreme event is caused by human influences on the climate. That assumption is wrong in two ways. First, climate is about the statistical properties of weather over decades, not single events. And second, there are only about 130 years of reliable observational records that can be analyzed statistically. That brief interval does not begin to contain all of the extreme events that the climate system can create on its own. Over geologic time the climate system has generated an (essentially) infinite variety of weather patterns and extremes that humans have never observed, and thus are absent from the databases used to determine extreme statistics.¹ [see *Perils of short data records* below]. For that reason, attributing an extreme event unprecedented in the record requires assumptions about the magnitude of natural variations.

This is especially true for precipitation events. The hydrological literature has long noted the phenomenon of *Long Term Persistence* (LTP) in rainfall data (Hurst 1951, Cohn and Lins 2005, Markonis and Koutsoyiannis 2015). LTP has a formal mathematical definition but it can be thought of intuitively as the presence of natural variations with strong autocorrelation properties that result in cycle-like behavior on long time scales. The presence of LTP requires long records to accurately estimate variability. Analysis of records short relative to the LTP scale will tend to underestimate variability, therefore overstating the significance of apparent trends and underestimating the likelihood of extreme events (Cohn and Lins 2005).

A good example of LTP is the eight-century long record of the annual minimum height of the Nile River observed at Roda Island in Cairo shown below. Since human influences on the global climate were negligible before the 20th century, the century-scale variability of the thirty-year average is entirely natural; Egyptians of the seventh and eight centuries would have been incorrect to assume that the worsening drought during that time was the “new normal.”

¹ For example, under the simplest statistical assumptions there is a 37 percent chance that a 100-year event is NOT present in a century-long record.



With these caveats in mind we examine the evidence for changes in selected weather and climate extremes. It has become routine in media discussions, government and private sector discussions and even in some academic literature to make generalized assertions that extreme weather of all types is getting worse due to GHGs and climate change. Yet expert assessments have not typically drawn such sweeping conclusions and instead have emphasized the difficulty both of identifying specific trends and establishing a causal connection with anthropogenic forcing. In the Appendix to this chapter we provide excerpts of these finding from previous IPCC and NCA assessments.

8.2 Extreme weather trends at global and continental scale

8.2.1 Tropical Cyclones (TCs)

Hurricane strength records for the North Atlantic and the Western Pacific go back to 1950 and the record does not show an increase in either total or major TCs. Figure 8.1 was published by Roger Pielke Jr. as an update to the Best Track data series originally presented in Weinkle et al. (2012).

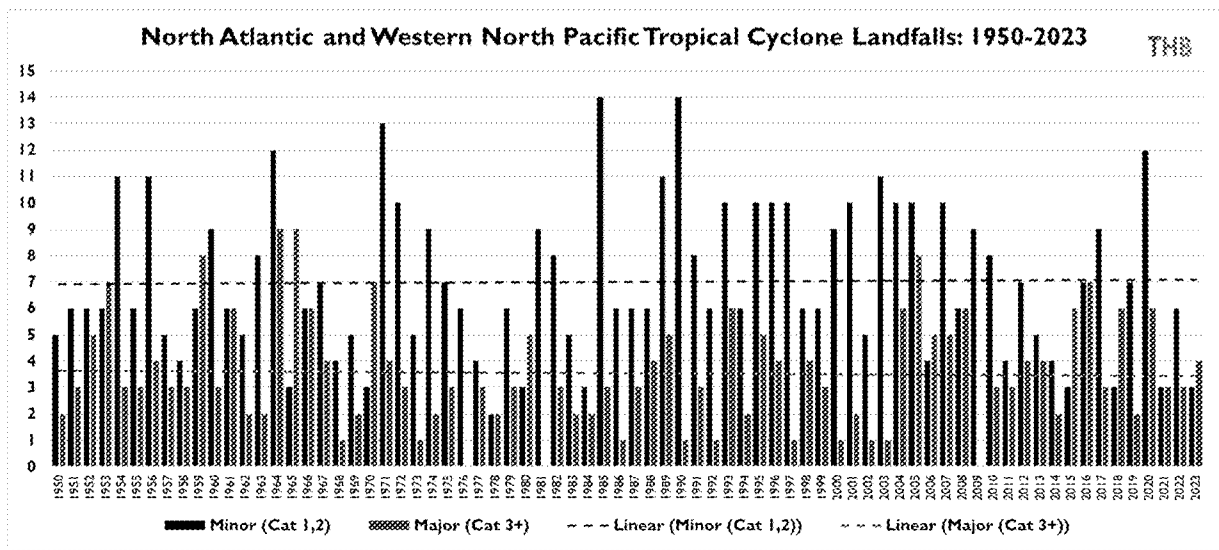


Figure 8.1. Tropical Cyclone Landfalls. Source: <https://rogerpielkejr.substack.com/p/global-tropical-cyclones>, Weinkle et al. (2012)

Similarly, Figure 8.2 shows that both all hurricanes and major hurricanes have not become more common since 1980, the period of rapidly growing human influences. In fact, both numbers have trended down slightly since the 1990s:

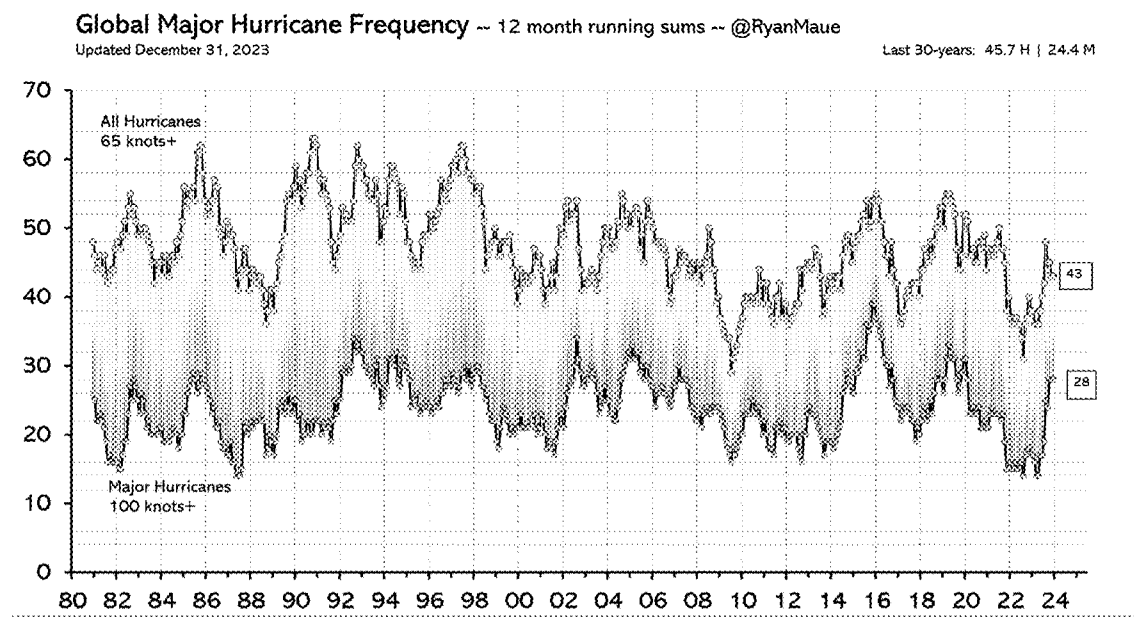


Figure 8.2: Global hurricane frequency. Source: Maue (2024)

A metric that combines the number, duration, and strength of TCs is the Accumulated Cyclone Energy (ACE) Index maintained at Colorado State University, shown in Figure 8.3. It clearly shows no long-term increase, in fact declining slightly since 1990.

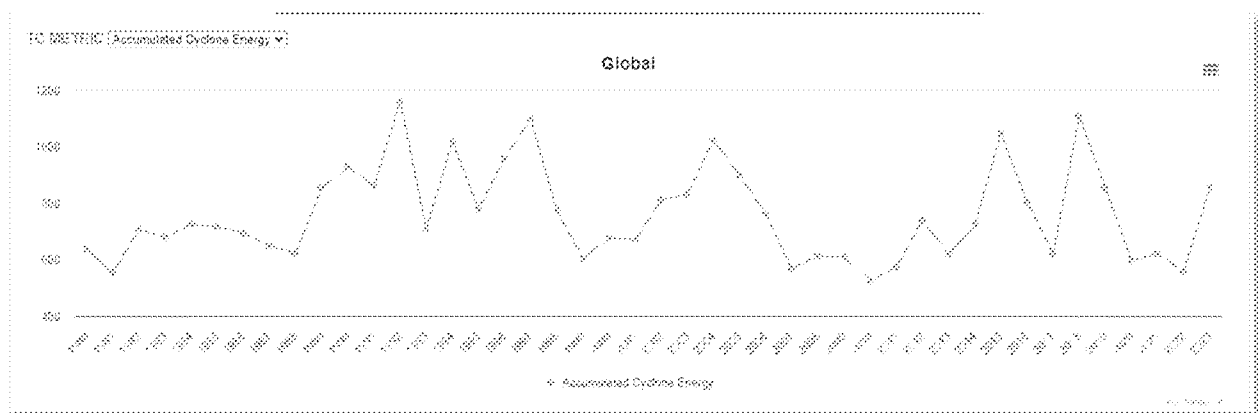


Figure 8.3: Global Accumulated Cyclone Energy. Source: Klotzbach (2025)

<https://tropical.atmos.colostate.edu/Realtime/index.php?arch&loc=global>

Note that Tu et al. (2024) report that the Power Dissipation Index (PDI), another different measure that combines hurricane number, duration, and strength, has either remained unchanged or has declined in all global oceanic basins since the mid-1990s.

Today's global climate simulations are too coarse to project changes in TCs directly. Rather, projections are derived from finer “downscaled” simulations or proxies involving sea surface temperatures, winds, and aerosols. By those methods, a warming climate is expected to show declining hurricane formation rates. (Chand et al. 2022). Climate models also project fewer Tropical Cyclones under future global warming, and even though models project they will increase in strength, the annual averages of rainfall maxima decline (Stansfield et al. 2020).

8.2.2 Wildfires

As shown in Figures 8.4 and 8.5 global wildfire activity as measured by European Space Agency peaked over a decade ago and shows a downward trend since.

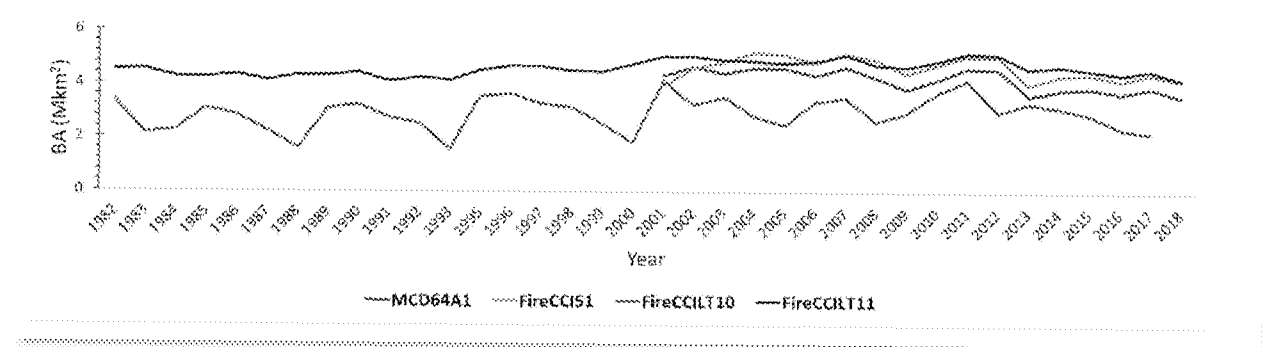


Figure 8.4: Global wildfire 1982-2018. Source: Copied from Oton et al. (2021). Note: the different coloured lines represent different data products based on satellites and algorithms used.

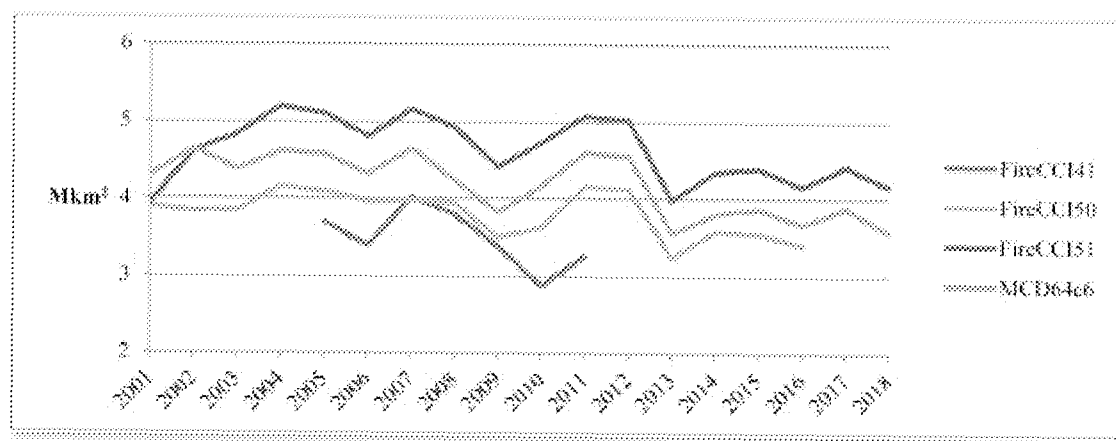


Figure 8.5: Global wildfire 2001-2018. Source: Copied from Lizundia-Loiola et al. (2021). Note: the different coloured lines represent different data products based on satellites and algorithms used

US data from the National Interagency Fire Centre (NIFC) from 1926 to 2023 are shown in Figure 8.6.

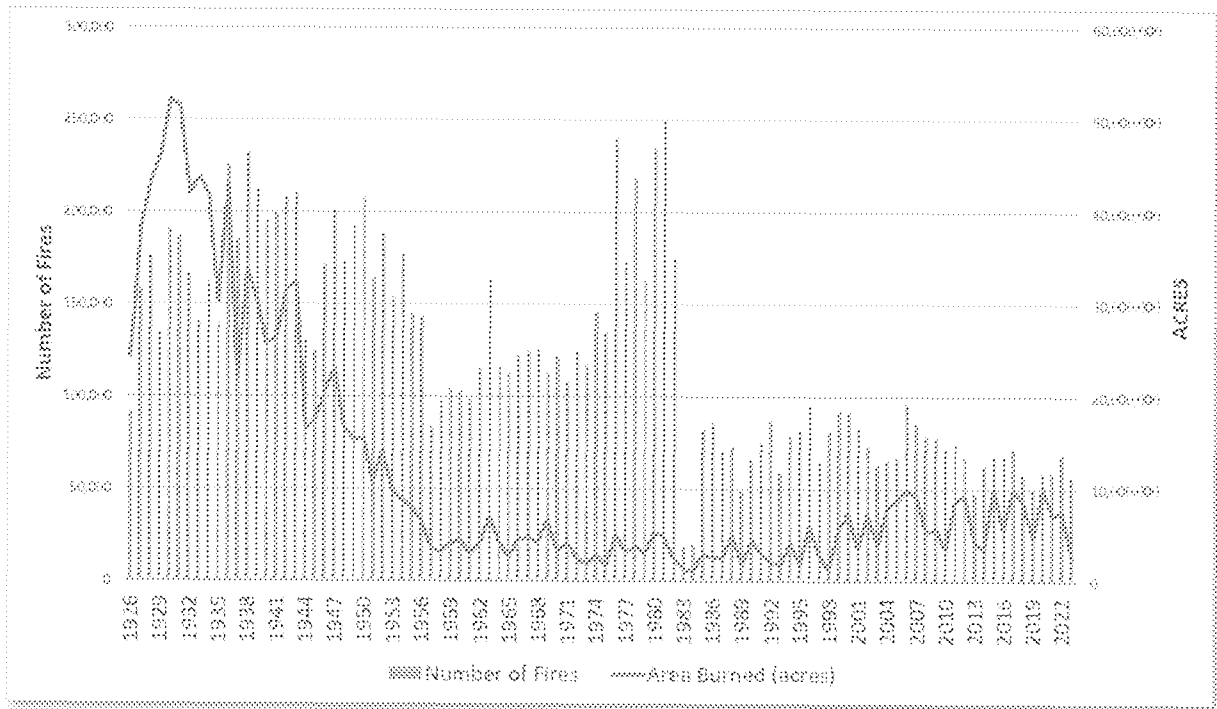


Figure 8.6: US wildfires 1926 to 2023. Source: National InterAgency Fire Centre data Pre-2017 (archived)

https://web.archive.org/web/20200212033452/https://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html. 2018-2023: <https://www.nifc.gov/fire-information/statistics/wildfires>

Note the NIFC has removed the pre-1960 data from its current website. They claim it is because measurement methods changed after 1960. This explanation seems inadequate since agencies blend temperature and extreme weather data series in other contexts when measurement systems changed. In this case if anything the measurement of wildfires has improved since the early 20th century so any bias will be towards understating early wildfire counts. Nonetheless just focusing on the post-1985 interval the number of fires is not increasing. The area burned did increase but only until about 2007.

It is difficult to establish a natural baseline for wildfire activity because of active fire suppression activity since 1900. Paleoclimatic evidence indicates, however, that past wildfire activity was much higher than at present. Marlon et al. (2012) used sedimentary charcoal layers to reconstruct fire history of western US for the past 1400 years. They also fit a model to predict expected fire activity as a function of climatic conditions. The results are summarized in Figure 8.7 below (from Figure 2 in their paper).

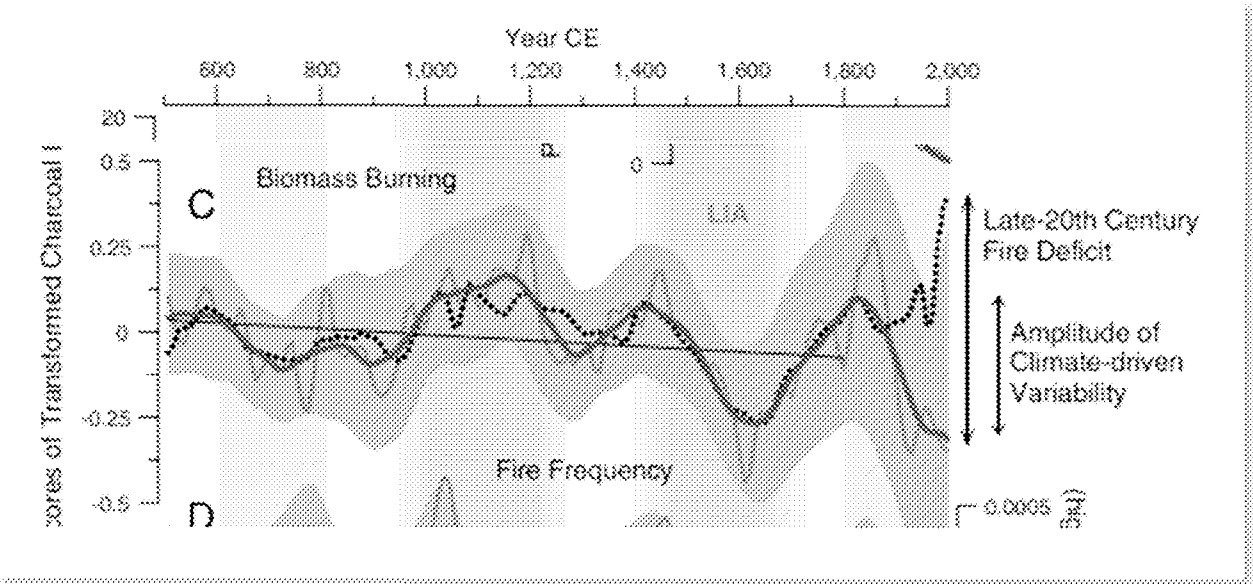


Figure 8.7: Fire frequency and fire deficit in the US. Source: Copied from Marlon et al. (2012)

In their figure the red line shows the smoothed charcoal record and the black dotted line shows the predicted charcoal record based on the statistical model. The gap at the end implies there has been a growing wildfire deficit over the 20th century. In other words, however much fire was observed in the 20th century it was less than what would have been observed in previous centuries based on the climatic conditions. Parks et al. (2025) likewise find that despite the recent increase in wildfire burn area in North America, a significant wildfire deficit remains relative to historical wildfire regimes.

8.2.3 Precipitation

Figure 8.8 shows that US long term data from NOAA shows an insignificantly increasing tendency toward extreme wetness (+0.001% per year)

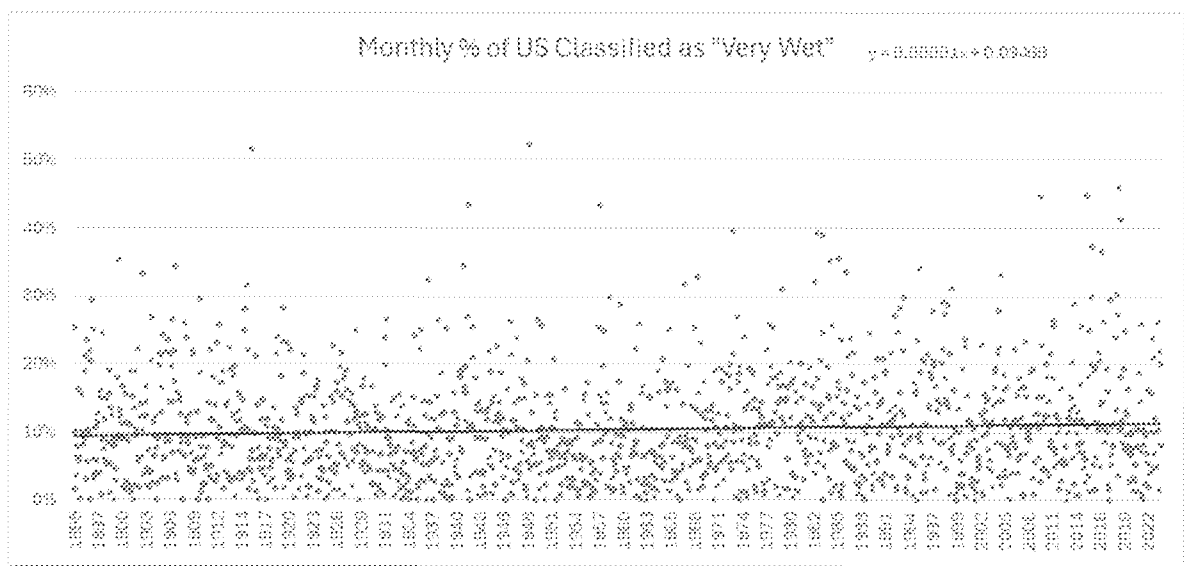


Figure 8.8: Long term US wetness (%). Source: NOAA
<https://www.ncei.noaa.gov/access/monitoring/uspa/wet-dry/0>

Precipitation will be discussed further in the review of CONUS data below.

8.2.4 Drought

As shown in Figure 8.9 US long term data (NOAA) shows an insignificantly declining tendency toward extreme dryness (-0.00001% per year)

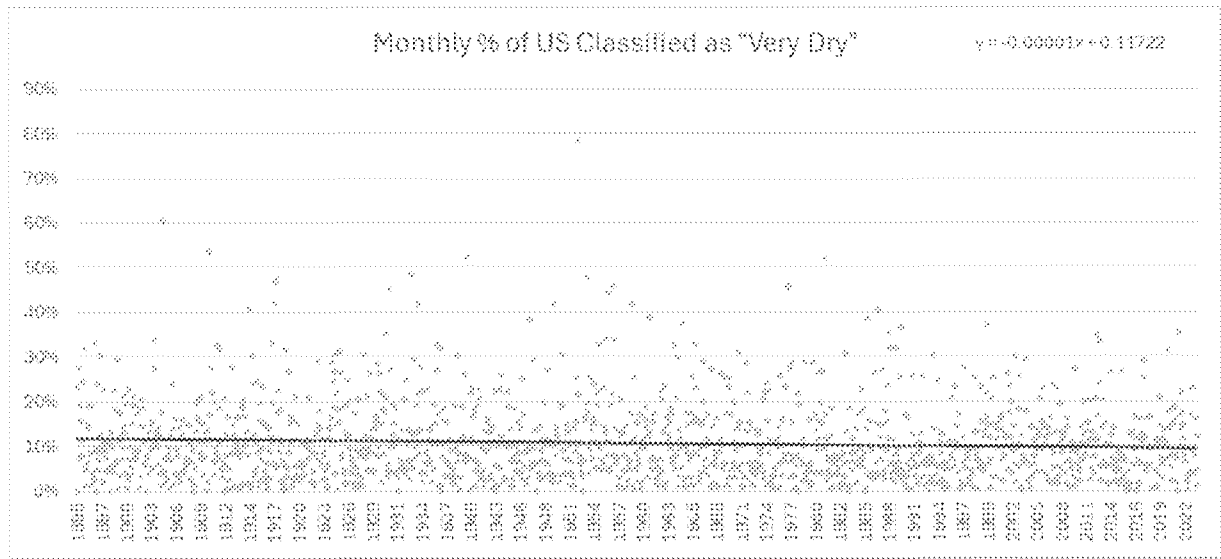


Figure 8.9: US dryness (%) 1895—2023. Source: NOAA
<https://www.ncei.noaa.gov/access/monitoring/uspa/wet-dry/0>

Kogan et al. (2020) examines a 38-year high-resolution satellite-based drought measure and concludes that global drought has not intensified and is not connected to climate change: "it is possible to state firmly that global and main grain countries' drought area and intensity trends have not been following global climate warming since 1980's."

8.3 Temperature and precipitation extremes in the Contiguous US (CONUS)

8.3.1 CONUS daily temperatures are becoming less extreme

Daily maximum temperatures in the warm season (TMax, May-Sep) and daily minimum temperatures in the cold season (TMin, Dec-Mar) are available beginning in Dec 1898 (126 years). The dataset consists of 1,211 CONUS stations designated as United States Historical Climate Network or USHCN stations (Quinlan et al. 1987, Karl et al. 1990). These stations were selected by NOAA as having the fewest problematic issues with gaps, station moves and instrument changes. Where gaps still exist, nearby stations (bias-corrected) were merged so that the median volume of data available

for a station is 98%. Although there are certainly errors in the dataset, with over 1,000 stations we can have relatively high confidence in any underlying signal that might be discovered.

We begin with the question of whether the occurrence of daily record high or low temperatures changed has changed since Dec 1898. Each warm-season has 153 days (1 May to 30 Sep) and each cold-season has 122 days (1 Dec to 31 Mar). For each station and day, we calculated the year in which the record highest (lowest) temperature occurred. With 126 years of observations, if there were no temperature trends over time, the expected number of records for TMax would be 1.21 ($=153/126$) per year and for TMin 0.96 ($=122/126$) per year. Figure 8.10 indicates the observed distribution in time of the occurrence of these extreme events.

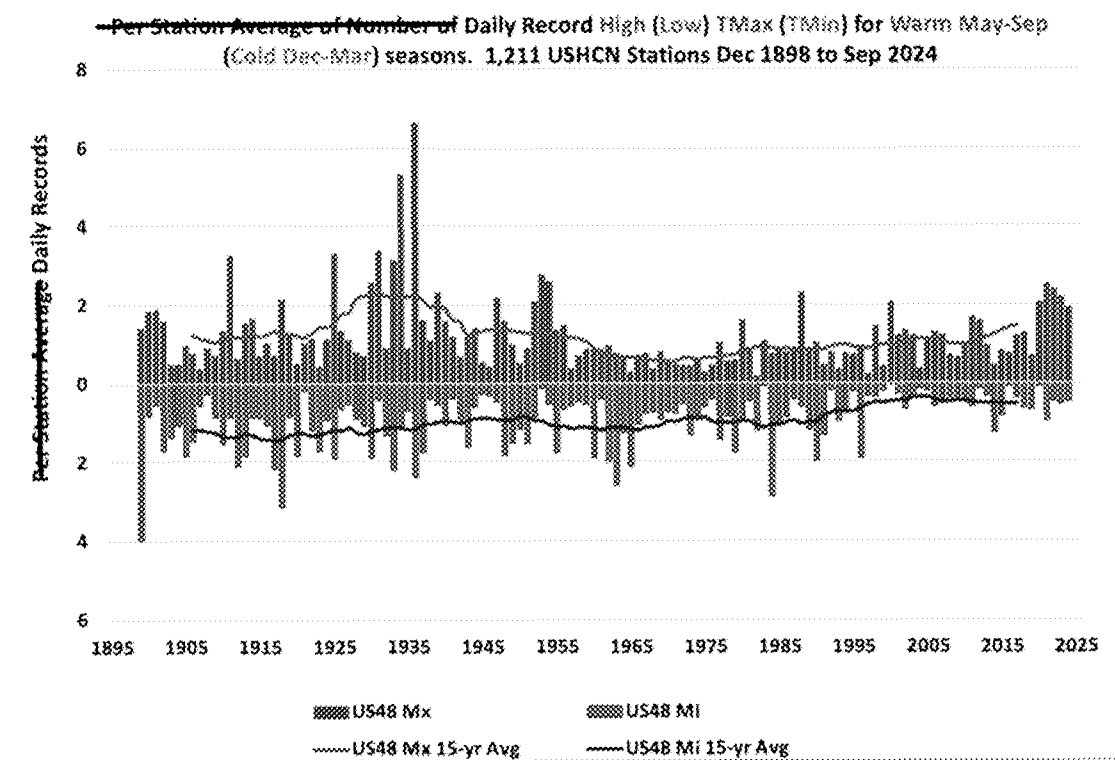


Figure 8.10 Number of daily record High (red) and Low (blue) for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92% of observations in the 126-year period since Dec 1898.

The results indicate a common feature in many metrics of warm-season extremes in the CONUS - the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. On a per-station average, 60% of the TMax records and 59% of the TMin records occurred in the first half of the period (1899-1961).

On the cold side, the Valentine's Day Arctic outbreak in Feb 1899 stands as the most extensive cold extreme experienced by the CONUS, with 1917 2nd. The frequency of cold records has declined, especially over the last quarter of the period in which only 13% of the extreme cold events were measured. In contrast, 25% of the extreme TMax records were achieved in the last quarter in accordance with statistical expectations. These general features have been noted in past assessments

(IPCC AR5, IPCC AR6, NCA4, NCA5). Combining the two records the overall reduction in numbers of both cold and hot extremes over the past century indicates a climate less prone to extremes.

This pattern is also shown in Figure 8.11. For each station and for each year the hottest warm season and coldest cold-season temperatures were calculated and converted to anomalies relative to the station's long term warm and cold season (respectively) averages. Then the differences between these were computed by station and geographically-averaged over all stations, thus yielding an annual measure of the expected range of local extreme temperatures for each year. Figure 8.11 shows the 15-year trailing average of this measure which has clearly declined over the past century.

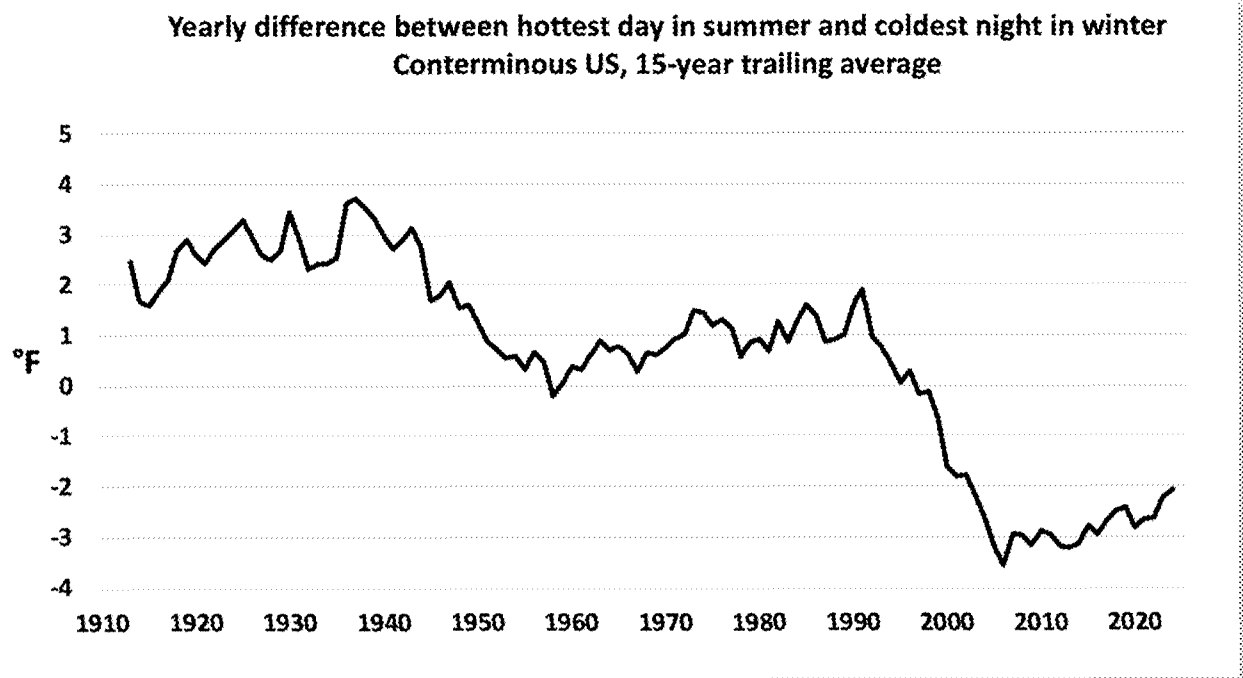


Figure 8.11. 15-year trailing average of the difference each year of each station's hottest warm-season TMax and coldest cold-season TMin relative to the long-term average.

The average difference for each station between the hottest summer TMax and coldest winter TMin has declined about 5°F in the past 126 years. The decline is due mostly to warming winter TMin, but a decline in the magnitude of summer TMax is also a factor. The rise in TMin has been strongly related to the growing presence of manufactured surfaces around the weather stations over the last 100+ years (Spencer et al. 2025).

Summarizing Figures 8.10 and 8.11, while temperature extremes are regularly experienced in the US and attract a great deal of media attention, long term records show the US climate has become less extreme over time (milder) when measured in terms of the range between warm season maxima and cold season minima.

8.3.2 Exceedances of a heat threshold

Under the heading of “The Risk of Temperature Extremes is Changing”, the most recent US National Climate Assessment report (NCA5) notes the increase in a threshold metric of number of days at or above 95°F, stating,

“The western US has been particularly affected by extreme heat since the 1980s ..., experiencing a larger increase in days over 95°F, as would be expected given the greater warming in that region relative to the eastern US. Several major heatwaves have affected the US since 2018, including a record-shattering event in the Pacific Northwest in 2021.”

Are the occurrences of 95°F days changing? In a climate as varied as that of CONUS, threshold statistics can be misleading. A region with many stations that have near 95°F TMax average temperatures in the summer might see large swings in the metric when only small changes in average temperature occur. Elsewhere with stations that either rarely or virtually always achieve 95°F TMax temperatures, a small change will not impact the results much at all. In the past 126 years, the average CONUS station experienced 129 days exceeding 95°F per 6-yr period, but the regional values range from 278 in the Southern Plains to 9 in the Northeast. Thus, one needs to view such threshold analyses with caution.

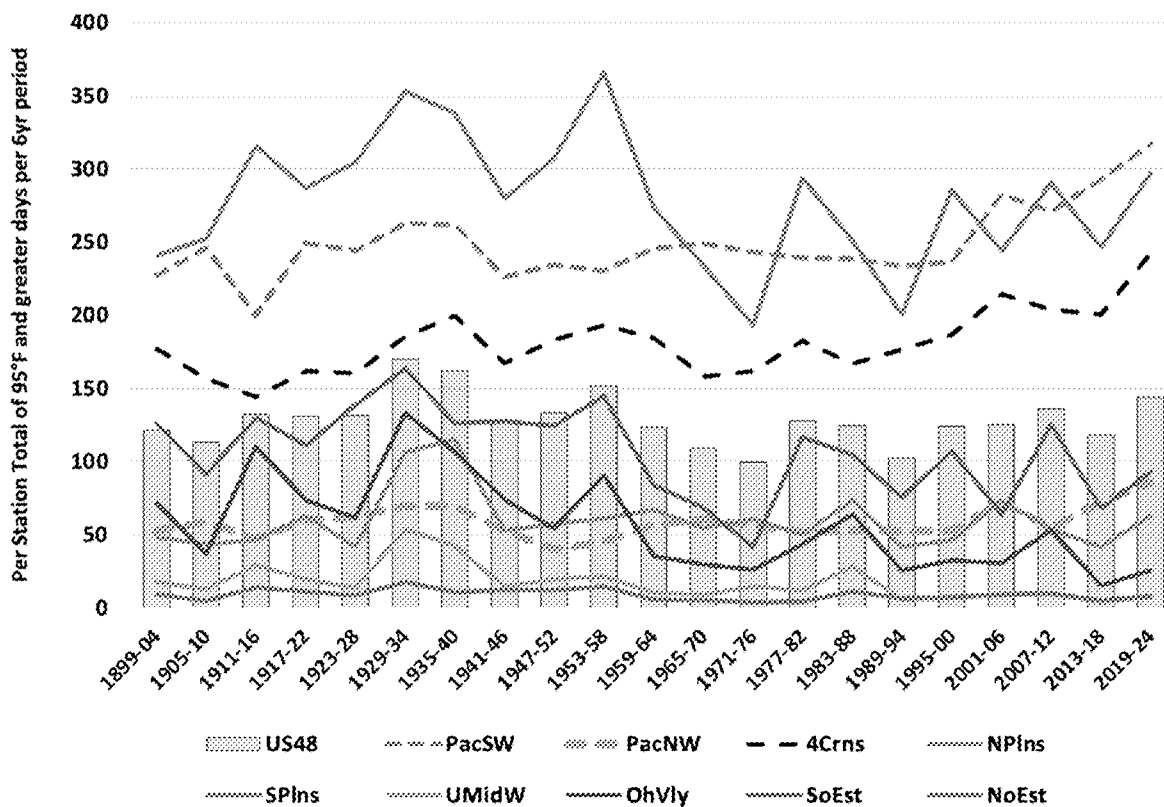


Figure 8.12. Total number of days $\geq 95^{\circ}\text{F}$ in 6-yr periods, US 48 (bars) and regions (lines).

In Fig. 8.12 we see that only three of the nine regions, all in the West, have experienced upward trends in the number of 95°F or hotter days (dashed lines). The CONUS as a whole has not and the other six regions have experienced declines.

The Pacific NW heatwave of 2021 is referenced as of the NCA5 claim, an event we examine more closely in Section 6.4. The evidence indicates it was a “black swan” event; *i.e.*, a single, unprecedented event in the record, not part of a pattern of increasing extreme heat. For example, the 5-day average tropospheric grid-point temperature anomaly over the Pacific NW during that event was +10.8 C, the most extreme NH grid point summer anomaly in the 46 years from over 4 million grids. In contrast, the global anomaly during that time was virtually zero (+0.03 C, Mass et al. 2024).

The heading “The Risk of Temperature Extremes is Changing” suggests positive trends are now being observed in threshold temperatures on a widespread basis, but that is not evidenced in the combined CONUS results of the figures above.

8.3.3 Heatwaves

Heatwaves (consecutive days that exceed an extreme threshold) have a greater societal impact than a single daily record. We measure “Heatwave Days” here as the count of all days in May-Sep each year that exceed the 90th percentile and that lie within a run of at least six consecutive days. This is equivalent to the method used in NCA5 except that the reference period here is the entire record 1899-2024 while NCA5 truncated the reference period to 1961-1990, a cool time. That truncation boosts positive results (days exceeding the 90th percentile) in periods warmer than the reference period, especially starting in 1960 and moving to the present (see *Urban Influences* below).

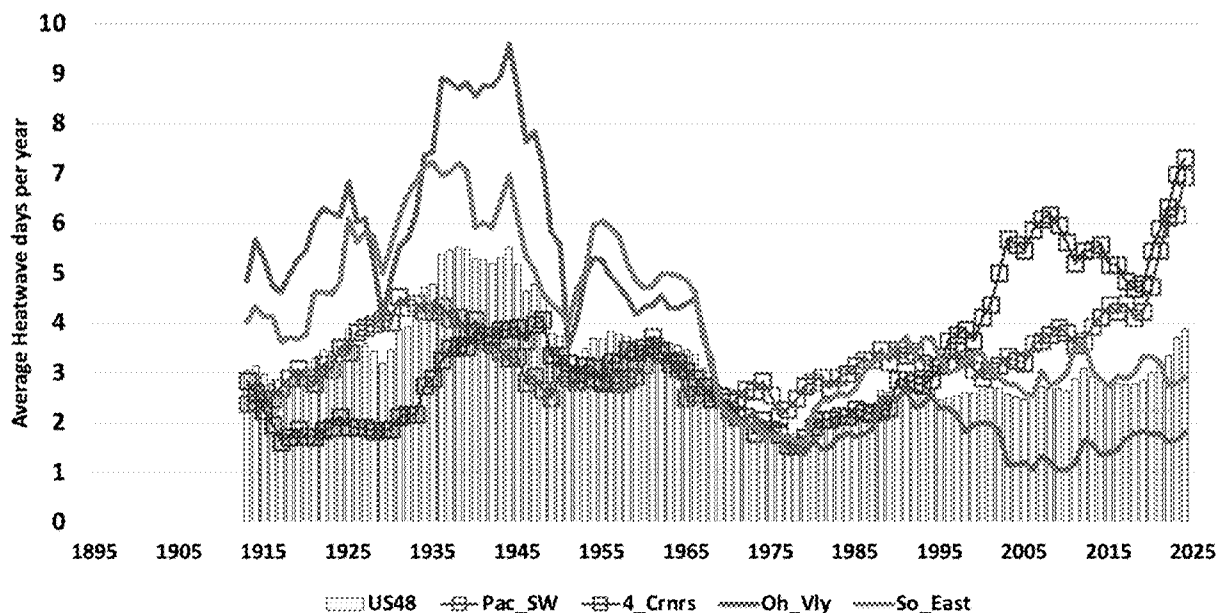


Figure 8.13 15-year trailing average of number of heatwave days per year per station in the CONUS (bars) and four regions: Pac_SW (purple squares, CA, NV), 4_Crnrs (red squares, AZ,NM,UT,CO), Oh_Vly (blue, MO, IL, KY, TN, IN, OH, WV) and So_East (green, MS, AL, GA, FL, SC, NC, VA).

Figure 8.13 indicates again the excessive heat of the first half of the 20th century, primarily in the eastern two-thirds of the nation, as seen in the regional values for the Ohio Valley and the Southeast as examples. The West has seen a recent increase of heatwave days and the two regions with the highest number are shown, the Pacific Southwest and the Four-Corners (NCA5). This indicates that the background warm season circulation favored heatwaves in the eastern portions of the country in the first half of the 20th century, but in the 21st century the patterns have favored heatwaves in the West. For CONUS as a whole, heatwaves are no more common today than they were a century ago.

Of interest here is the regional variation of this metric. The four northern regions (Pacific NW, Northern Plains, Upper Midwest, and Northeast) on average experience 15 to 27 heatwave days per 15-year period. In contrast, the five southern regions (Pacific Southwest, 4-Corners, Southern Plains, Ohio Valley and Southeast) see 37 to 54 such days, essentially twice as many. This suggests the summer circulation pattern is more prone to stationary events in the southern regions while transient systems in the northern regions are more common and thus cut short these potentially longer events.

Urban influences

The NCA5 directs readers to the website <https://www.globalchange.gov/indicators/heat-waves> (USGCRP 2023) to view the number of urban heatwaves by decade from the 1960s. The figure shows a monotonic increase in each decade from 2 occurrences per year in the 1960s to 6 in the 2020s. The definition of a heatwave is an unusual but practical measure of human discomfort - a period of at least 2 consecutive days when the minimum apparent temperature (combination of temperature and humidity) exceeds the 85th percentile. Note too, the dataset is limited to the 50 largest U.S. cities.

These increasing values since 1960 presented in USGCRP (2023) are entirely reasonable, but are unrelated to GHG emissions for at least two reasons. Urbanization in these cities is a major factor in the rise of TMin relative to co-located TMax and relative to TMin at rural stations. Also, the 1960s was the coldest decade and 1970s the second coldest decade since the 1910's, so this starting date preconditions the time series to show increases. This does not dismiss the real rise in nighttime temperatures in major U. S. cities and the societal impacts associated with these changes. However, we note for a variety of reasons, that summer TMax (especially in rural areas) serves as better response variable for detecting potential changes in heatwaves influenced by changes in the background climate due, for example, to increasing GHGs (Christy et al. 2009). For the CONUS as a whole, the evidence in this section suggests GHG emissions have had little-to-no effect on heatwaves.

8.3.4 Extremes in daily precipitation.

Because precipitation involves a discrete phase change (water vapor to liquid), it is stochastic and episodic character and therefore requires careful statistical treatment to understand variability over long time periods (see 8.1 *Introduction*). The US National Climate Assessments (NCA4, NCA5) have highlighted an increase in the occurrence of the heaviest precipitation events (defined in different ways) primarily in the eastern half of the CONUS, especially the Northeast, when starting in either 1901 or 1958. Interestingly, the regional variations indicate that the largest increases in extreme events are in the Northeast and the smallest in the West, a trend counter to the changes in temperature extremes.

McKittrick and Christy (2019) examined long-term and consistent station observations of daily precipitation to test some of these NCA claims for the Southeast and West Coast. When the time series were extended back in time (as far as 1872 in some cases) or when starting later (1978), there were no significant trends for either region. For this report we update these findings with similarly

constructed observations from 29 stations on the Pacific Coast (1893ff from San Diego CA to Blaine WA, see Figure 8.14), 24 stations in the humid Southeast (1872ff from Austin TX to Washington DC, see Figure 8.15), and 21 stations in the Northeast (1888ff from Buffalo NY to Gardiner ME, see Figure 8.16).

In the Pacific region, over the whole sample average precipitation trends downward, being significant only in Astoria. Rainfall variance increases, significantly only in Big Sur. The trend in daily maximum precipitation is positive and significant in Aberdeen and Big Sur and negative and significant in Newport and insignificant elsewhere. Averaged over all stations in the region none of these three trend parameters is statistically significant.

In the Southeast region over the whole sample the trend in average precipitation is positive and significant only in Mobile and Quitman, the trend in rainfall variance is positive and significant only in Mobile and the trend in daily maximum precipitation is positive and significant only in Vicksburg and Norfolk. Averaged over all stations in the region none of these three trend parameters is statistically significant.

The Northeast region exhibits a pattern of increasing average rainfall. The trend in average precipitation is positive and significant in 9 of 21 locations and in the region averaged overall. The trend in rainfall variance is positive and significant only in Portland, Albany and Buffalo and insignificant elsewhere and not in the regional average. The trend in daily maximum precipitation is positive and significant only in Portland ME and Gardiner ME and insignificant elsewhere and not in the regional average.

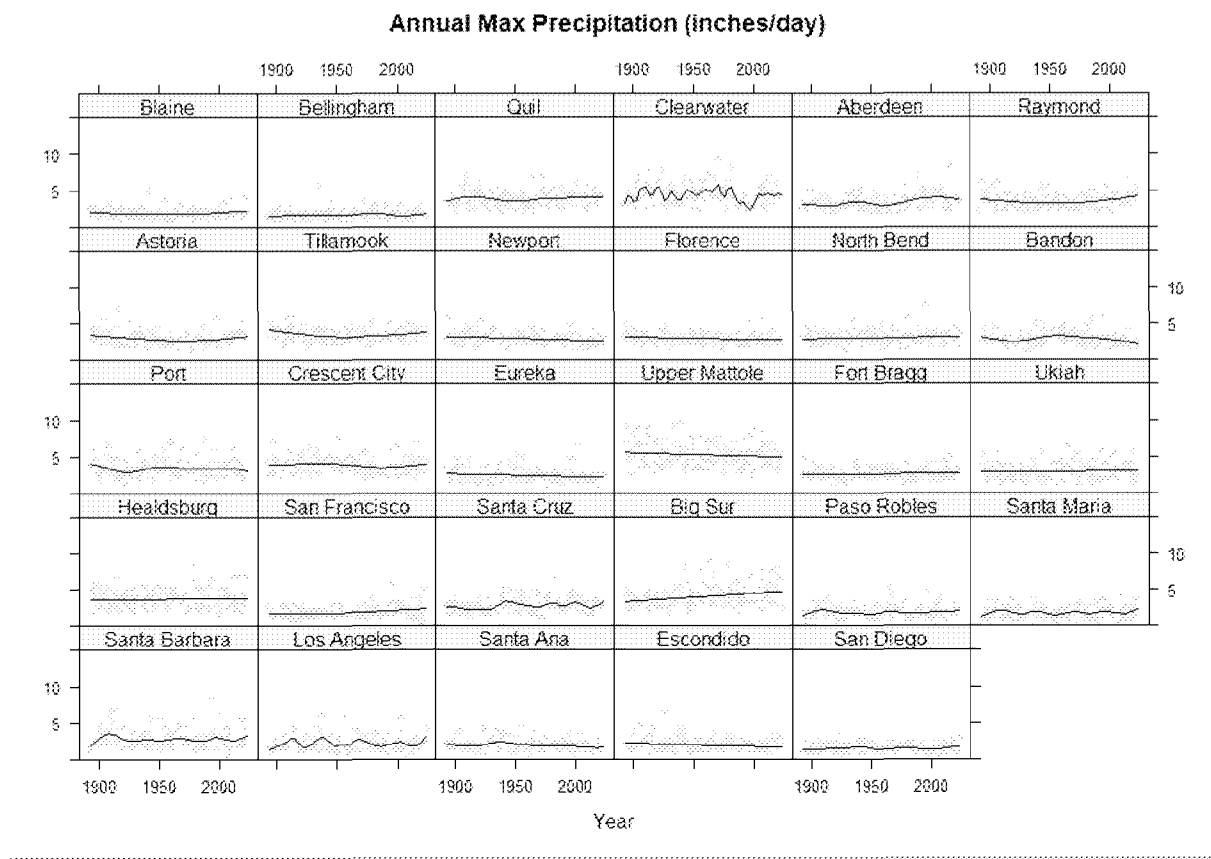


Figure 8.11 Annual maximum precipitation for 29 Pacific stations 1893 to present

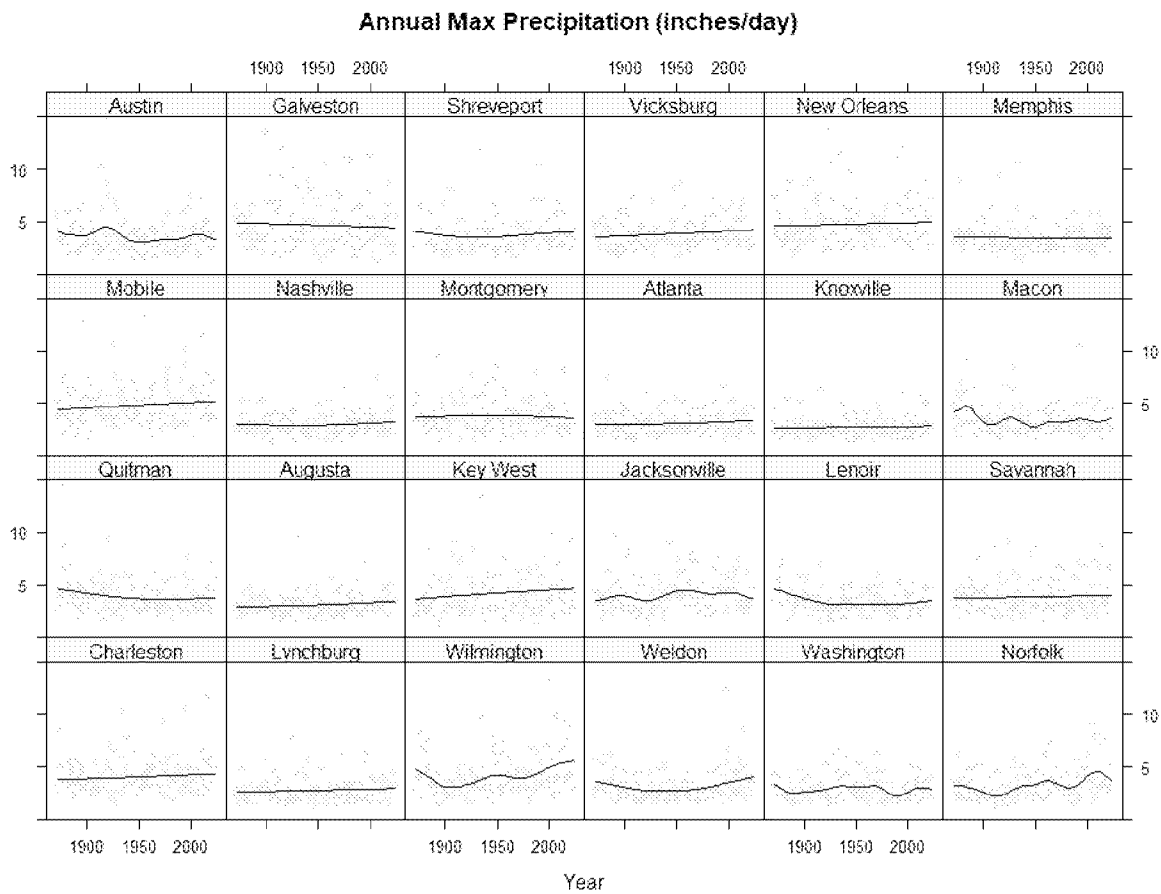


Figure 8.12 Annual maximum precipitation for 24 Southeast stations 1872 to present

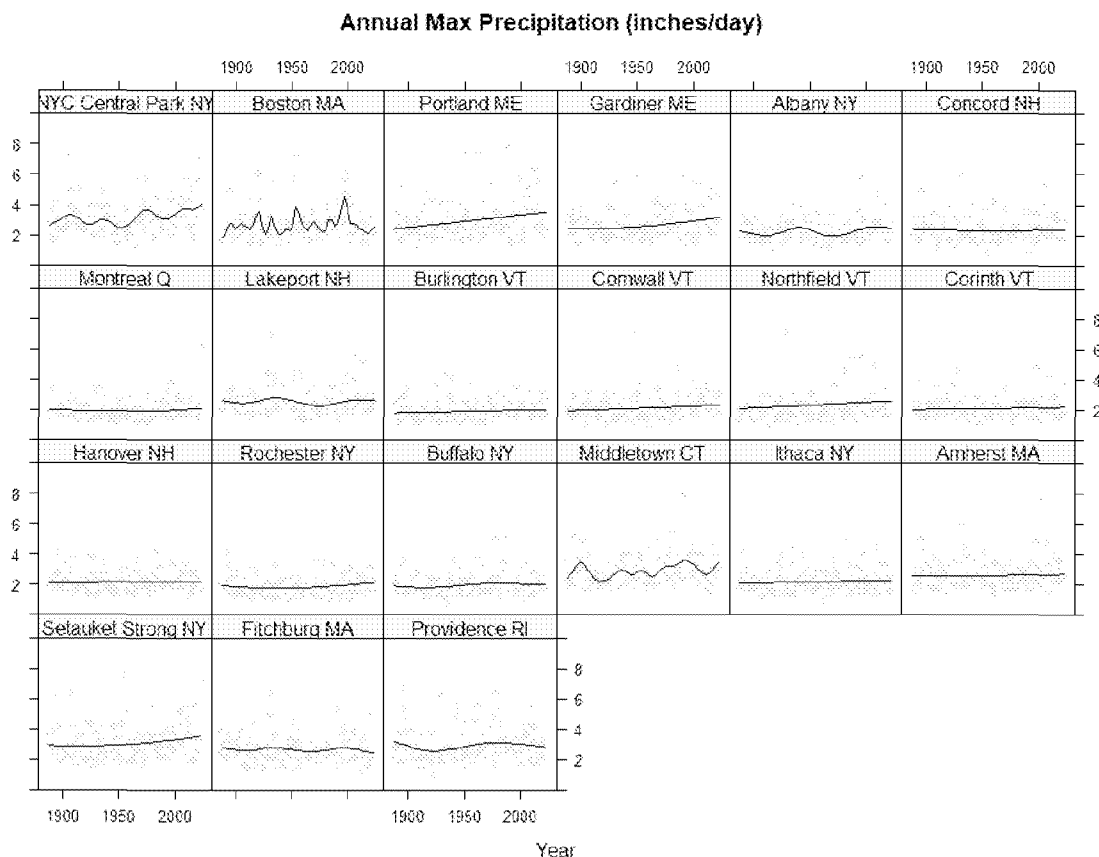


Figure 8.13 Annual maximum precipitation for 21 Northeast stations 1888 to present

Pacific Coast heavy rainfall events

The Pacific Coast receives considerable precipitation from Atmospheric River (AR) events which often last more than a day or two (e.g., Gershunov et al. 2017, Pan et al. 2024). The worst-known such event in recent history was the ArkStorm that occurred between December 1861 and January 1862, which dumped nearly 10 feet of rain in parts of California and submerged the entire Central Valley for weeks under as much as 15 feet of water (Brewer 1930, Null and Hulbert 2007). Paleoclimate research has found six megastorms more severe than 1861–1862 in California during the last 1800 years, occurring at intervals of 300 years or so (Porter et al. 2011).

SIDEBAR: Perils of short data records

San Francisco provides a good case study of the limitation of using short historical samples to characterize natural variability of extreme events. Suppose we use a 130-year sample of daily San Francisco precipitation from 1895 to 2024 and we look for 3-day, 5-day, 14-day and 30-day rainfall records. The results are as shown in Table 8.1.

Event	Record (inches)	Year
3-day	6.94	2023
5-day	8.55	2023
14-day	12.62	2023

30-day	18.93	1998
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Table 8.1: Extreme rainfall records, San Francisco, 1895-2024.

The records all cluster in the more recent data. 2023 appears to be an exceptional year and since it is near the end of the sample it might suggest that the climate has shifted into a more hazardous state, perhaps as a result of human influences.

But the picture is very different if we use a sample that begins 45 years earlier, in 1850. Table 8.2 shows that the record-setting events then all happened in the 1860s. Furthermore 2023 is now not even in 2nd place but falls to 3rd or 4th. Also, comparing the records of the two charts the extreme precipitation events in 1862 and 1867 involved considerably more rainfall than the 1998 and 2023 events, with 14- and 30-day totals about 50 percent higher.

Event	Record (inches)	Year	Rank of 130-yr extreme
3-day	8.85	1867	3
5-day	9.80	1867	3
14-day	19.05	1862	4
30-day	28.25	1862	2

Table 8.2: Extreme rainfall records, San Francisco, 1850-2024.

The range of natural variability is made even more remarkable when paleoclimate evidence is examined. Porter et al. (2011) discovered that in the past 1,800 years at least six megastorms were more intense than the devastating 1861-62 ArkStorm that struck the region. Evidently such extreme events have impacted the region about every 300 years, though not since 1895.

This example illustrates the limitations of using relatively short climate periods (~130 years) to assess the character and range of natural variability in general and of extreme events in particular. Accurate representation of the full range of natural variability is necessary for any attribution analyses (see 6.4). Infrastructure planners, emergency management institutions and attribution scientists would understand the significant mischaracterization of the magnitude of a future extreme if based only on the last 130 years. In this case, a single time-sample of 130 years provides an underestimation of the extreme value by up to 50% determined when adding only 45 more years of observations. Compared to millennial-scale paleoclimate evidence, an even greater underestimation would occur. An important lesson is that the climate can deliver great surprises on its own, even without human influences.

We examine occurrences of 5-day deluges as follows. In a 130-year span there are 26 5-year intervals. At each location we computed the 5-day precipitation totals throughout the year and selected the 26 highest values. A single year may have more than one of the 26 heaviest. Each of those can be thought of as 1-in-5yr events. If there are no trends in precipitation then the total number of these events across all stations should be evenly spread out over the years. In Fig. 8.14 we show the distribution in time of these events. The deluges associated with the massive 1997-98 El Niño event are readily apparent. While erratic, as is typical of these types of precipitation metrics, there is no indication of a tendency to become more frequent over time.

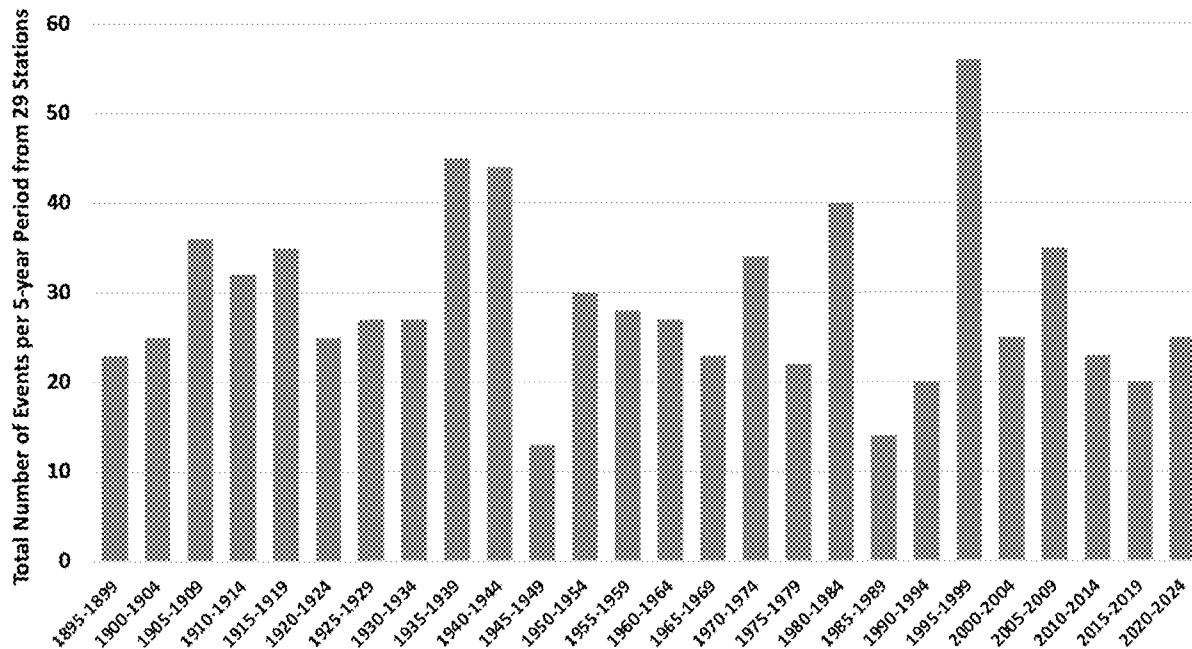


Figure 8.14. The time distribution by 5-year periods of the 26 heaviest occurrences for each station (i.e., nominal 1-in-5 year event).

Southeast heavy rainfall events

The temporal pattern of 5-day totals of the 1-in-5yr heavy events in the humid Southeast (Figure 8.15) is generally unremarkable, though a cluster of higher values appears in 1995 to 2019. The increase in those years is due largely to the 4 northeastern-most stations of Wilmington NC, Weldon NC, Washington DC, and Norfolk VA. This confirms the pattern indicated in NCA4 and NCA5 of a tendency for an increasing frequency of heavy events, due to a temporal clustering of tropical storms from eastern NC to Maine discussed below. Otherwise, the remaining 20 stations show an unremarkable temporal distribution of heavy events.

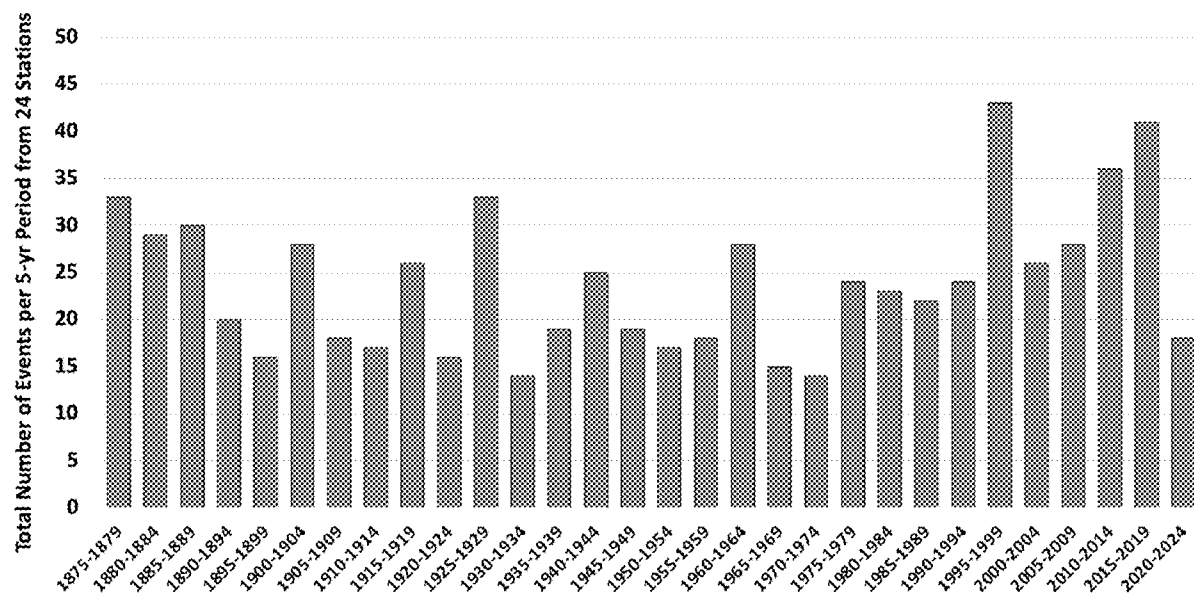


Figure 8.15. As above but for the 30 heaviest 1-in-5yr events for 24 stations in the humid Southeast from Austin TX to Washington DC in 5-year bins for 1875-2024.

Northwest heavy rainfall events

Fig. 8.16 shows the 27 (1-in-5yr) heaviest 3-day events for the last 135 years in 21 stations in the Northeast (including Montreal Canada). We use 3-day totals here as this produced the largest variations in time. In this region, 72% of the events occur during June to October and are dominated by tropical incursions of hurricanes, tropical storms or tropical storms that transition to extratropical systems. According to NCA4 and NCA5 this region experienced the largest increases in extreme events, so it shall be examined more closely.

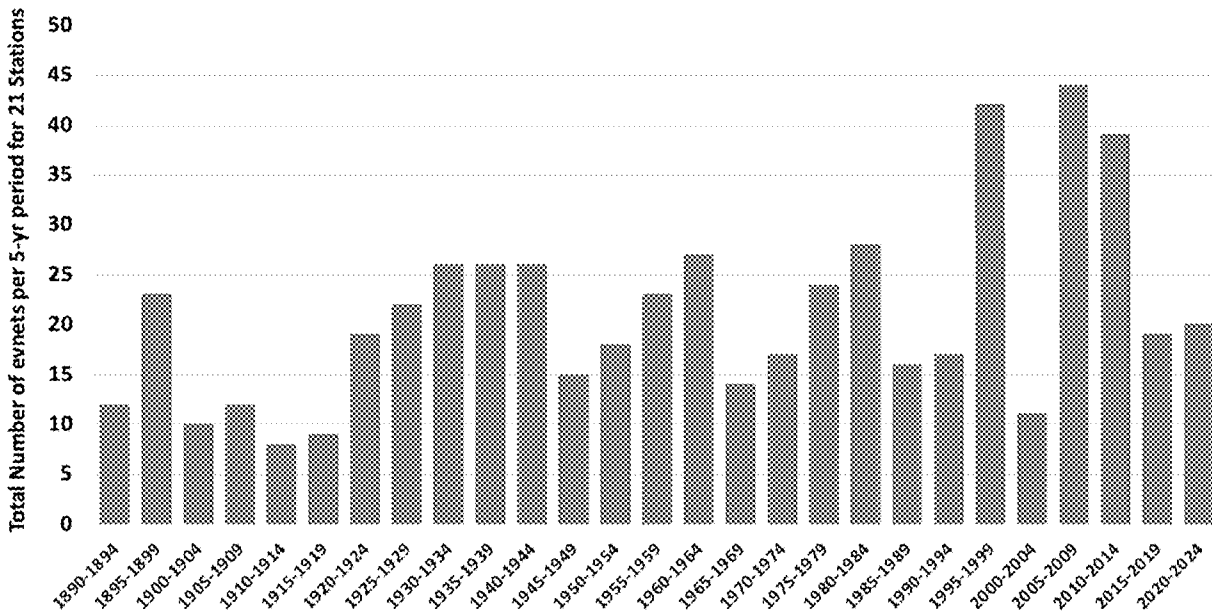


Figure 8.16. Time distribution of the heaviest 27 (1-in-5yr) heaviest 3-day precipitation events for 21 stations from NY to ME, including Montreal.

Howarth et al. (2019) report differences in the Northeast between two 18-year periods: 1979-96 and 1997-2014 (a similar region as in Fig. 8.16 that includes PA and NJ) of various precipitation extremes. One metric which indicated a dramatic increase (317%) was found for 24-hr events > 6 inches. This high increase is due to the very small numbers of such events of which there were only 6 in the first period and 25 in the second as reported for 58 stations. This high percentage increase is due to the very small numbers of the events; only 6 in the first period and 25 in the second. Most of the stations, did not record such an event suggesting these erratic, episodic events over brief, 18-yr periods, need scrutiny by additional statistical methods.

Using the information in Fig. 8.16 over the same years as Howarth et al. we find a 51% increase in the frequency of heavy events between the two periods. One can see in Fig. 8.16 that it was unfortunate that Howarth et al. ended in 2014 prior to a return to the long-term average of such events.

A feature of Howarth et al. is the use of single day totals which is questionable because extreme events are often spread across the time-of-observation boundary. Thus stations measuring at 0700 LT versus those at Midnight will have differing results for a particular event which would then have major impacts on counting these events. We use the 3-day totals in Fig. 8.16 to be sure to capture the extent of these extreme downpours. In any case, we can confirm that the period 1997 to 2014 experienced a cluster of heavier events as Howarth et al. have documented.

Howarth's most remarkable claim (317% increase in 6" days) is potentially misleading because it is a threshold statistic (see 8.3.2 above) and a ratio of small numbers over a short period. The result is not representative of *relative* extreme events for the whole region since the majority of stations never experienced a 6" total. Fig. 8.16 above determines the same number of events for each station (27 heaviest events) whose heaviest values ranged from 4.4" to 12.5" and their 27th heaviest values ranged from 3.3" to 5.0". This analysis thus allows each station to be equally represented. In other

words, if there is a region-wide increase in heavy events, it should be seen in the sum of all stations. Note too that the period of record here is 135 years vs. 36 years of Howarth et al. Except for three 5-year periods between 1995 and 2014 there is nothing statistically remarkable about the results in Fig. 8.16.

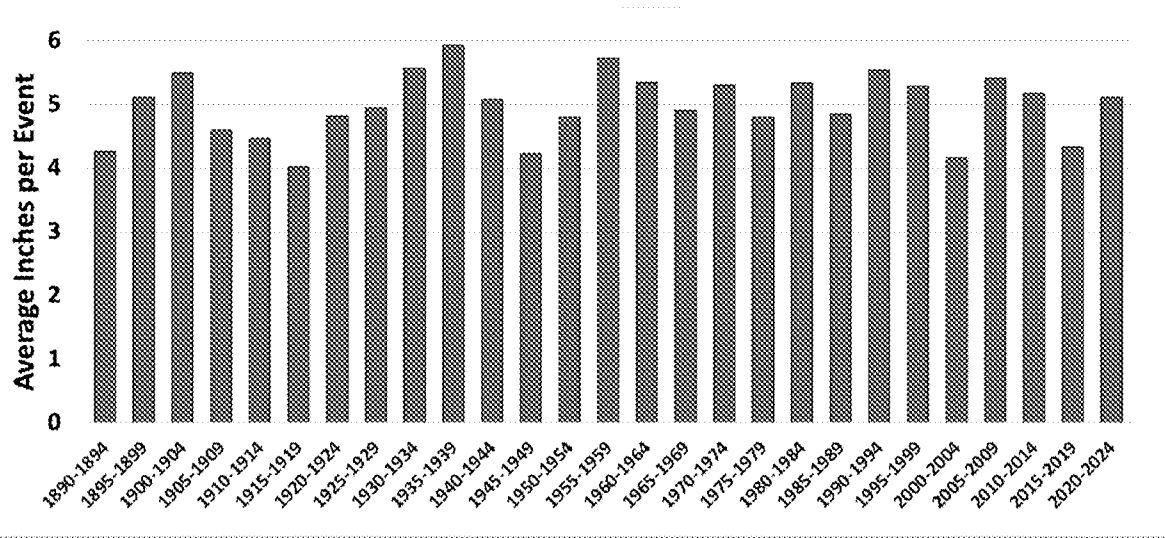


Figure 8.17. Average amount of precipitation falling in the 1-in-5yr events for the NE stations.

An interesting aspect of Northeast precipitation is that there has been no change in the amount of precipitation per heaviest event, as shown in Fig. 8.17. The trend is only $+0.02''/\text{decade}$. The highest amount, 1935-39, includes the Great New England Hurricane of 1938, one of the rare major (Category 3 or higher) hurricanes to strike the region. The results in Figs. 8.15 and 8.16 suggest that though there was an uptick in the number of events during the period 1995 to 2014; the events, individually, are not becoming more intense.

Jong et al. (2024) document the increase of tropical influences on precipitation events in the Northeast since 1959 and concluded, “The autumn extreme precipitation trend over the Northeast US is primarily attributed to tropical cyclone-related events since the 1990s.” The question then becomes, was the temporal clustering of tropical systems in 1997-2014 which affected the Northeast a response to increasing GHGs? Jong et al. examined CMIP-6 model output which suggests that there will be fewer such systems in the 21st century but that the intensity of the rainfall events might increase. This conjecture is not seen in Fig. 8.17 where the amount-per-event has remained steady over the 135-year period.

For substantial urban areas there is some evidence to indicate the heaviest rainfall events may be redistributed due to the impact urban infrastructure has on the local weather (e.g., Pielke Sr. et al. 2011, Zhang et al. 2018, Yang et al. 2024). Yang et al. state, “Cities that experience compact development tend to witness larger increases in extreme rainfall frequency over downtown than their rural surroundings, while the anomalies in extreme rainfall frequency diminish for cities with

dispersed development.” While this is an important insight to consider, the effect on the specific stations used in this analysis is unknown, or at least not detectable in Fig. 8.17.

In summary, the evidence from the historical record of extreme precipitation events in the CONUS is generally not consistent from region to region so that inferences regarding trends and their projections are wrought with significant uncertainty. In most regions and perhaps all, it is our opinion that the very nature of the erratic and episodic character of extreme precipitation events renders the discovery of statistically significant changes, including a relationship to CO₂ concentrations, a result yet to be achieved (McKittrick and Christy 2019).

8.4 Summary

Based on the content provided in the document, here are the five most important takeaways:

1. Limited Detection of Anthropogenic Signals: The IPCC has asserted high confidence in detecting an anthropogenic signal in only 4 out of 34 weather impact categories, and medium confidence in 4 more. For the remaining 26 categories, no anthropogenic signal is claimed to be detected.
2. Slow Emergence of Trends: Even under the most extreme forcing scenario (RCP8.5), the IPCC expects very few anthropogenic trends to emerge within this century for most weather impacts.
3. Natural Variability Dominance: Natural variability continues to dominate patterns of extreme weather systems. Simple assertions of trend detection are often complicated by regional heterogeneity and trend reversals over time.
4. RCP8.5 Scenario Implausibility: The document notes that the RCP8.5 scenario is described as an implausible high-end storyline, not a "base case" or "business-as-usual" projection.
5. Conflicting Messages on Attribution: The document mentions that AR6 (IPCC Sixth Assessment Report) offers conflicting messages about the attribution of extreme weather to anthropogenic causes, highlighting the complexity and uncertainty in this area of climate science.

These takeaways emphasize the nuanced and complex nature of attributing extreme weather events to climate change, and the importance of considering natural variability and uncertainty in climate projections.

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Appendix: Review of IPCC and NCA Findings on Extreme Weather

The sources we review will be denoted as follows:

SREX: The IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (2012)

AR5: The IPCC *Fifth Assessment Report Working Group 1* (2013).

AR6: The IPCC *Sixth Assessment Report Working Group 1* (2021).

NCA17: The *US Climate Science Special Report of the Fourth National Climate Assessment* (2017) Volume I Chapter 6.

8A.1 Overview: IPCC Assessment of signal emergence in extreme weather types (AR6 WG1 Table 12.12)

Table 8A.1 reproduces the findings of AR6 Table 12.12 which indicates, for 34 major weather event and impact types, whether a signal of anthropogenic forcing has been detected in the historical record (column 1), whether such a signal is likely to emerge by 2050 under the extreme RCP8.5 scenario (column 2) and whether it is likely to emerge by 2100 under RCP8.5 forcing (column 3). It should be borne in mind that the latter two columns suffer from the deficiencies of GCMs discussed in Chapter XX. And as we discussed in Ch X on attribution, AR6 offers conflicting messages about attribution of extreme weather. Nevertheless, we provide this Table for reference.

Several patterns stand out. First, detection of an anthropogenic signal is asserted with *high confidence* in only four of the 34 weather impact categories, and with *medium confidence* in a further four. The IPCC does NOT claim to have detected an anthropogenic signal in the remaining 26 categories. Of the four *high confidence* assertions, two are for changes in average temperatures (air and ocean), which are not measures of extreme weather. Further, two of the four *medium confidence* assertions are related to ocean chemistry and also not related to extreme weather. The IPCC does NOT assert a detectable human influence on many non-temperature weather features such as wind, precipitation, flooding, and drought.

Second, columns 2 and 3 show that the IPCC expects very few anthropogenic trends to emerge within this century, *even under the most extreme forcing scenario*. As we discuss in Section 4.2 the RCP8.5 scenario is an implausible high-end storyline, not a “base case” or “business-as-usual” projection. Even so, most weather impacts are not expected to show an anthropogenic signal this century. Natural variability dominates patterns of extreme weather systems and simplistic assertions of trend detection are frequently undermined by regional heterogeneity and trend reversals over time.

Climate Impact Driver Type	Climate Impact Driver Category	Already Emerged in the Historical Record?	Emerging by 2050 in Most Extreme CO2 Emissions Scenario?	Emerging by 2100 in Most Extreme CO2 Emissions Scenario?
Heat & Cold	Average air temperature	YES in most regions	YES	YES
	More heat extremes	YES in most regions	YES in land regions	YES
	Fewer cold extremes	YES in a few regions	YES in many regions	YES
	Less frost	NO	NO	NO
Wet & Dry	Average Precip. (Increase or Decrease)	NO	YES (incr) YES (decr)	YES (incr) YES (decr)
	River flooding	NO	NO	NO

	Heavy precip & pluvial flood	NO	NO	YES in a few regions
	Landslide	NO	NO	NO
	Aridity	NO	NO	NO
	Hydrologic Drought	NO	NO	NO
	Agricultural & ecological drought	NO	NO	NO
	Fire weather	NO	NO	NO
Wind	Average wind speed	NO	NO	NO
	Severe wind storm	NO	NO	NO
	Tropical cyclone	NO	NO	NO
	Sand and dust storm	NO	NO	NO
Snow and Ice	Snow, glacier & ice sheet	NO	YES in a few regions	YES Arctic snow
	Permafrost	YES	YES	YES
	Lake & river ice	NO	YES	YES
	Arctic sea ice	YES	YES	YES
	Antarctic sea ice	NO	YES	YES
	Heavy snowfall and ice storm	NO	NO	NO
	Hail	NO	NO	NO
Coastal	Snow avalanche	NO	NO	NO
	Relative sea level	NO	YES	YES
	Coastal flood	NO	NO	NO
Open Ocean	Coastal erosion	NO	NO	NO
	Average ocean temperature	YES	YES	YES
	Marine heat wave	NO	NO	NO
	Ocean acidity	NO	YES	YES
	Ocean salinity	YES	YES	YES
Other	Dissolved oxygen	YES (Pacific & S. Ocean)	YES	YES
	Air pollution weather	NO	NO	NO
	Solar or IR radiation at surface	NO	NO	NO

Table 8A.1. IPCC AR6 summary of the probable emergence of an anthropogenic signal above natural climate variability for all global or regional “climate impact drivers” (CIDs) of concern for humans and ecosystems in response to increasing atmospheric greenhouse gas concentrations (primarily CO₂). Source: Table adapted from report of Working Group I, Table 12.12). Red = high confidence; yellow = medium confidence; green = no anthropogenic signal detectable above natural variability (50% confidence).

Taking wind as an example, the IPCC claims that an anthropogenic signal has NOT emerged in average wind speeds, severe windstorms, tropical cyclones, or sand and dust storms, and none are expected to emerge this century even under an extreme emissions scenario. The same applies to drought and fire weather. This table alone suffices to illustrate the gap between IPCC expert assessments of extreme weather and discussions in the popular media and political arenas. As we show below the Table reflects longstanding conclusions of the IPCC and other assessment bodies. In the next few sections we will simply present without comment excerpts from past assessment reports.² In selecting these excerpts, we’ve focused on the highest-level summaries to avoid accusations of bias through “cherry picking”.

² In these excerpts we have added **bold-face** emphasis, while *italicized* emphasis on confidence terms appears in the original sources. Citations in quoted text can be found in the underlying reports but are not reproduced here.

8A.2 Flooding

SREX (p. 176)

In the United States and Canada during the 20th century and in the early 21st century, **there is no compelling evidence for climate-driven changes in the magnitude or frequency of floods.**

AR5 (p. 214)

AR4 WGI Chapter 3 (Trenberth et al., 2007) did not assess changes in floods but AR4 WGII concluded that **there was not a general global trend in the incidence of floods** (Kundzewicz et al., 2007). SREX went further to suggest that there was low agreement and thus *low confidence* at the global scale regarding changes in the magnitude or frequency of floods or even the sign of changes.

AR5 WGII assesses floods in regional detail accounting for the fact that trends in floods are strongly influenced by changes in river management (see also Section 2.5.2). Although the most evident flood trends appear to be in northern high latitudes, where observed warming trends have been largest, in some regions no evidence of a trend in extreme flooding has been found, for example, over Russia based on daily river discharge (Shiklomanov et al., 2007). Other studies for Europe (Hannaford and Marsh, 2008; Renard et al., 2008; Petrow and Merz, 2009; Stahl et al., 2010) and Asia (Jiang et al., 2008; Delgado et al., 2010) show evidence for upward, downward or no trend in the magnitude and frequency of floods, so that there is currently no clear and widespread evidence for observed changes in flooding except for the earlier spring flow in snow-dominated regions (Seneviratne et al., 2012).

In summary, **there continues to be a lack of evidence and thus *low confidence* regarding the sign of trend in the magnitude and/or frequency of floods on a global scale.**

AR6 (Ch 11 p. 1568)

The SREX (Seneviratne et al., 2012) assessed *low confidence* for observed changes in the magnitude or frequency of floods at the global scale. This assessment was confirmed by the AR5 report (Hartmann et al., 2013). The SR15 (Hoegh-Guldberg et al., 2018) found increases in flood frequency and extreme streamflow in some regions, but decreases in other regions. **While the number of studies on flood trends has increased since the AR5 report, and there were also new analyses after the release of SR15 (Berghuijs et al., 2017; Blöschl et al., 2019; Gudmundsson et al., 2019), hydrological literature on observed flood changes is heterogeneous, focusing at regional and sub-regional basin scales, making it difficult to synthesise at the global and sometimes regional scales.**

In summary, the seasonality of floods has changed in cold regions where snowmelt dominates the flow regime in response to warming (*high confidence*). **Confidence about peak flow trends over past decades on the global scale is low, but there are regions experiencing increases**, including parts of Asia, southern South America, the northeast USA, northwestern Europe, and the Amazon, **and regions experiencing decreases**, including parts of the Mediterranean, Australia, Africa, and the southwestern USA.

US NCA17 pp. 240-41:

“The IPCC AR5 did not attribute changes in flooding to anthropogenic influence nor report detectable changes in flooding magnitude, duration, or frequency. Trends in extreme high values of streamflow are mixed across the United States. Analysis of 200 U.S. stream gauges

indicates areas of both increasing and decreasing flooding magnitude but does not provide robust evidence that these trends are attributable to human influences...

The complex mix of processes complicates the formal attribution of observed flooding trends to anthropogenic climate change and suggests that additional scientific rigor is needed in flood attribution studies. As noted above, precipitation increases have been found to strongly influence changes in flood statistics. However, in U.S. regions, **no formal attribution of precipitation changes to anthropogenic forcing has been made so far, so indirect attribution of flooding changes is not possible. Hence, no formal attribution of observed flooding changes to anthropogenic forcing has been claimed.**"

8A.3 Heatwaves

AR5 (p. 212 WG1)

Table 2.13 shows that there has been a *likely* increasing trend in the frequency of heatwaves since the middle of the 20th century in Europe and Australia and across much of Asia where there are sufficient data. However, confidence on a global scale is *medium* owing to lack of studies over Africa and South America but also in part owing to differences in trends depending on how heatwaves are defined (Perkins et al., 2012). Using monthly means as a proxy for heatwaves Coumou et al. (2013) and Hansen et al. (2012) indicate that record-breaking temperatures in recent decades substantially exceed what would be expected by chance but caution is required when making inferences between these studies and those that deal with multi-day events and/ or use more complex definitions for heatwave events. **There is also evidence in some regions that periods prior to the 1950s had more heatwaves (e.g., over the USA, the decade of the 1930s stands out and is also associated with extreme drought conditions** (Peterson et al., 2013) whereas conversely in other regions heatwave trends may have been underestimated owing to poor quality and/or consistency of data (e.g., Della-Marta et al. (2007a) over Western Europe; Kuglitsch et al. (2009, 2010) over the Mediterranean). Recent available studies also suggest that the number of cold spells has reduced significantly since the 1950s (Donat et al., 2013a, 2013c).

In summary, new analyses continue to support the AR4 and SREX conclusions that since about 1950 it is *very likely* that the numbers of cold days and nights have decreased and the numbers of warm days and nights have increased overall on the global scale, that is, for land areas with sufficient data. It is *likely* that such changes have also occurred across most of North America, Europe, Asia and Australia.

NCA17 (pp. 190-191)

Changes in warm extremes are more nuanced than changes in cold extremes. For instance, **the warmest daily temperature of the year increased in some parts of the West over the past century (Figure 6.3), but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease** (Table 6.2), most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]). The decreases in the eastern half of [the] Nation, particularly in the Great Plains, are mainly tied to the unprecedented summer heat of the 1930s Dust Bowl era, which was exacerbated by land-surface feedbacks driven by springtime precipitation deficits and land mismanagement. However, anthropogenic aerosol forcing may also have reduced summer temperatures in the Northeast and Southeast from the early 1950s to the mid-1970s, and agricultural intensification may have suppressed the hottest extremes in the Midwest.

Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). **Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter (Figure 6.4). As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s.**

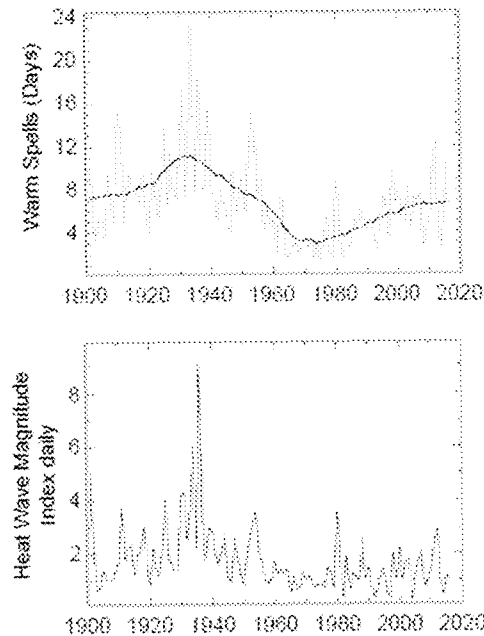


Figure 8.1: US Heat waves since 1900. Source: NCA17 Figure 6.4

AR6 (p. 1550)

In North America (Table 11.19), there is very robust evidence for a *very likely* increase in the intensity and frequency of hot extremes and decrease in the intensity and frequency of cold extremes for the whole continent, though there are substantial spatial and seasonal variations in the trends. Minimum temperatures display warming consistently across the continent, **while there are more contrasting trends in the annual maximum daily temperatures** in parts of the USA (Figure 11.9; Lee et al., 2014; van Oldenborgh et al., 2019; Dunn et al., 2020).

8A.4 Extreme snowfall events

Note: extreme snowfall events in the US northeast are assessed in relation to winter Extratropical Cyclone (ETC) activity.

AR6 Ch 11. p. 1593

There is *high confidence* that snowfall associated with winter ETCs will decrease in the future, because increases in tropospheric temperatures lead to a lower proportion of precipitation falling as snow (O’Gorman, 2014; Rhoades et al., 2018; Zarzycki, 2018). However, there is

medium confidence that extreme snowfall events associated with winter ETCs will change little in regions where snowfall will be supported in the future (O’Gorman, 2014; Zarzycki, 2018).

8A.5 Extreme precipitation

SREX (p. 142)

Recent studies have updated the assessment of the AR4, with more regional results now available (Table 3-2). Overall, this additional evidence confirms that **more locations and studies show an increase than a decrease in extreme precipitation, but that there are also wide regional and seasonal variations**, and trends in many regions are not statistically significant (Table 3-2)... Based on station data from Canada, the United States, and Mexico, Peterson et al. (2008a) reported that heavy precipitation has been increasing over 1950-2004, as well as the average amount of precipitation falling on days with precipitation.

AR5 (pp. 213-14)

In summary, further analyses continue to support the AR4 and SREX conclusions that **it is likely that since 1951 there have been statistically significant increases in the number of heavy precipitation events (e.g., above the 95th percentile) in more regions than there have been statistically significant decreases, but there are strong regional and subregional variations in the trends**. In particular, many regions present statistically non-significant or negative trends, and, where seasonal changes have been assessed, there are also variations between seasons (e.g., more consistent trends in winter than in summer in Europe). The overall most consistent trends towards heavier precipitation events are found in central North America (very likely increase) but assessment for Europe shows likely increases in more regions than decreases.

AR6 (p. 1560)

In North America, there is robust evidence that the magnitude and intensity of extreme precipitation has *very likely* increased since the 1950s. Both [one-day maxima] and [5-day maxima] have significantly increased in North America during 1950-2018 (Sun et al., 2020, also Figure 11.13). There is, however, regional diversity. In Canada, there is a lack of detectable trends in observed annual maximum daily (or shorter duration) precipitation (Shephard et al., 2014; Mekis et al., 2015; Vincent et al., 2018).

NCA17 pp. 213-14:

Detectability of trends (compared to internal variability) for a number of precipitation metrics over the continental United States has been examined; **however, trends identified for the U.S. regions have not been clearly attributed to anthropogenic forcing**. One study concluded that increasing precipitation trends in some north-central U.S. regions and the extreme annual anomalies there in 2013 were at least partly attributable to the combination of anthropogenic and natural forcing... **Based on current evidence, it is concluded that detectable but not attributable increases in mean precipitation have occurred over parts of the central United States**. Formal detection-attribution studies indicate a human contribution to extreme precipitation increases over the continental United States, but confidence is *low* based on those studies alone due to the short observational period, high natural variability, and model uncertainty.

In summary, based on available studies, it is concluded that for the continental United States there is *high confidence* in the detection of extreme precipitation increases, while there is *low confidence* in attributing the extreme precipitation changes purely to anthropogenic forcing.

8A.6 Tornadoes and severe convective storms

IPCC AR6 Sct. 11.7.3, p. 1594

Severe convective storms are convective systems that are associated with extreme phenomena such as tornadoes, hail, heavy precipitation (rain or snow), strong winds, and lightning.

The assessment of changes in severe convective storms in SREX (Chapter 3, Seneviratne et al., 2012) and AR5 (Chapter 12, Collins et al., 2013) is limited and focused mainly on tornadoes and hail storms. The SREX assessed that **there is *low confidence* in observed trends in tornadoes and hail** because of data inhomogeneities and inadequacies in monitoring systems. Subsequent literature assessed in the Climate Science Special Report (Kossin et al., 2017) led to the assessment of the observed tornado activity over the 2000s in the USA, with a decrease in the number of days per year with tornadoes and an increase in the number of tornadoes on these days (*medium confidence*). However, **there is *low confidence* in past trends for hail and severe thunderstorm winds**. Climate models consistently project environmental changes that would support an increase in the frequency and intensity of severe thunderstorms that combine tornadoes, hail, and winds (*high confidence*), but there is *low confidence* in the details of the projected increase.

... In summary, because the definition of severe convective storms varies depending on the literature and the region, it is not straightforward to make a synthesizing view of observed trends in severe convective storms in different regions. In particular, **observational trends in tornadoes, hail, and lightning associated with severe convective storms are not robustly detected** due to insufficient coverage of the long-term observations. There is *medium confidence* that the mean annual number of tornadoes in the USA has remained relatively constant, but their variability of occurrence has increased since the 1970s, particularly over the 2000s, with **a decrease in the number of days per year, and an increase in the number of tornadoes on these days** (*high confidence*). Detected tornadoes have also increased in Europe, but the trend depends on the density of observations.

... It is extremely difficult to detect differences in time and space of severe convective storms (Kunkel et al., 2013). Although some ingredients that are favourable for severe thunderstorms have increased over the years, others have not; thus, **overall, changes in the frequency of environments favourable for severe thunderstorms have not been statistically significant**... For hailstorms, such as those that caused disasters in the USA in 2018, detection of the role of climate change in changing hail storms is more difficult, because hail storms are not, in general, directly simulated by convection-permitting models and not adequately represented by the environmental parameters of coarse-resolution GCMs (Mahoney, 2020).

In summary, **it is extremely difficult to detect and attribute changes in severe convective storms**. There is limited evidence that extreme precipitation associated with severe convective storms has increased in some cases.

8A.7 Hurricanes and Tropical Cyclones

SREX (p. 159):

There have been no significant trends observed in global tropical cyclone frequency records, including over the present 40-year period of satellite observations (e.g., Webster et al., 2005). Regional trends in tropical cyclone frequency have been identified in the North Atlantic, but the fidelity of these trends is debated (Holland and Webster, 2007; Landsea, 2007; Mann et al., 2007a). Different methods for estimating undercounts in the earlier part of the North Atlantic tropical cyclone record provide mixed conclusions (Chang and Guo, 2007; Mann et al., 2007b; Kunkel et al., 2008; Vecchi and Knutson, 2008). Regional trends have not been detected in other oceans (Chan and Xu, 2009; Kubota and Chan, 2009; Callaghan and Power, 2011). **It thus remains uncertain whether any observed increases in tropical cyclone frequency on time scales longer than about 40 years are robust**, after accounting for past changes in observing capabilities (Knutson et al., 2010).

AR5 (pp. 216-17):

Current data sets indicate no significant observed trends in global tropical cyclone frequency over the past century and it remains uncertain whether any reported long-term increases in tropical cyclone frequency are robust, after accounting for past changes in observing capabilities (Knutson et al., 2010). **No robust trends in annual numbers of tropical storms, hurricanes and major hurricanes counts have been identified** over the past 100 years in the North Atlantic basin. Measures of land-falling tropical cyclone frequency (Figure 2.34) are generally considered to be more reliable than counts of all storms which tend to be strongly influenced by those that are weak and/or short lived. Callaghan and Power (2011) find a statistically significant decrease in Eastern Australia land-falling tropical cyclones since the late 19th century although including 2010/2011 season data this trend becomes non-significant (i.e., a trend of zero lies just inside the 90% confidence interval). Significant trends are not found in other oceans on shorter time scales (Chan and Xu, 2009; Kubota and Chan, 2009; Mohapatra et al., 2011; Weinkle et al., 2012), although Grinsted et al. (2012) find a significant positive trend in eastern USA using tide-gauge data from 1923–2008 as a proxy for storm surges associated with land-falling hurricanes. Differences between tropical cyclone studies highlight the challenges that still lie ahead in assessing long-term trends.

In summary, this assessment does not revise the SREX conclusion of *low confidence* that any reported long-term (centennial) increases in tropical cyclone activity are robust, after accounting for past changes in observing capabilities. More recent assessments indicate that **it is unlikely that annual numbers of tropical storms, hurricanes and major hurricanes counts have increased over the past 100 years in the North Atlantic basin**. Evidence, however, is for a virtually certain increase in the frequency and intensity of the strongest tropical cyclones since the 1970s in that region.

AR6 (p. 1585)

There is low confidence in most reported long-term (multidecadal to centennial) trends in TC frequency- or intensity-based metrics due to changes in the technology used to collect the best-track data. This should not be interpreted as implying that no physical (real) trends exist, but rather as indicating that either the quality or the temporal length of the data is not adequate to provide robust trend detection statements, particularly in the presence of multidecadal variability.

There are previous and ongoing efforts to homogenize the best-track data (Elsner et al., 2008; Kossin et al., 2013, 2020; Choy et al., 2015; Landsea, 2015; Emanuel et al., 2018) and there is substantial literature that finds positive trends in intensity-related metrics in the best-track during the “satellite period”, which is generally limited to the past ~40 years (Kang and Elsner, 2012; Kishtawal et al., 2012; Kossin et al., 2013, 2020; Mei and Xie, 2016; Zhao et al., 2018; Tauvale and Tsuboki, 2019). **When best-track trends are tested using homogenized data, the intensity trends generally remain positive, but are smaller in amplitude (Kossin et al., 2013; Holland and Bruyère, 2014). Kossin et al. (2020) extended the homogenized TC intensity record to the period 1979–2017 and identified significant global increases in major TC exceedance probability of about 6% per decade.**³ In addition to trends in TC intensity, there is evidence that TC intensification rates and the frequency of rapid intensification events have increased within the satellite era (Kishtawal et al. 2012; Balaguru et al., 2018; Bhatia et al., 2018). The increase in intensification rates is found in the best-track as well as the homogenized intensity data.

A subset of the best-track data corresponding to hurricanes that have directly impacted the United States since 1900 is considered to be reliable, and shows no trend in the frequency of U.S. landfall events (Knutson et al., 2019).

8A.8 Droughts

US NCA17 REPORT (Ch. 8, Wehner et al. 2017)

p. 231:

Recent droughts and associated heat waves have reached record intensity in some regions of the United States; however, by geographical scale and duration, the Dust Bowl era of the 1930s remains the benchmark drought and extreme heat event in the historical record (very high confidence). **While by some measures drought has decreased over much of the continental United States in association with long-term increases in precipitation, neither the precipitation increases nor inferred drought decreases have been confidently attributed to anthropogenic forcing.**

The human effect on recent major U.S. droughts is complicated. Little evidence is found for a human influence on observed precipitation deficits, but much evidence is found for a human influence on surface soil moisture deficits due to increased evapotranspiration caused by higher temperatures. (*High confidence*)

³ The underlined text referenced a study (Kossin et al. 2020) that later retracted a portion of its findings. Those authors assembled a data set on global TC incidence spanning 1979 to 2017 from which they claimed that the global fraction of TCs reaching major status (Cat 3–5) rose from 27% during 1979-1997 to 31% during 1998-2017 and that the increase was statistically significant. However, closer examination of their results showed a significant increase only in the North Atlantic (18% to 34%) whereas changes in all other basins (Eastern Pacific, Western Pacific, North Indian, South Indian, South Pacific) were not statistically significant. In a subsequent correction (<https://www.pnas.org/doi/10.1073/pnas.2021573117>), Kossin et al. stated that the global probability of observing a major TC rose from 34% during 1979-1997 to 37% in the later period and that the evidence for statistical significance was now weaker. Nevertheless, the authors claimed that the correction did not affect their conclusions.

p. 233:

Drought is, of course, directly connected to seasonal precipitation totals. Figure 7.1 shows detectable observed recent changes in seasonal precipitation. In fact, the increases in observed summer and fall precipitation are at odds with the projections in Figure 7.5. **As a consequence of this increased precipitation, drought statistics over the entire CONUS have declined.**

SREX (p. 170)

From a paleoclimate perspective recent droughts are not unprecedented, with severe ‘megadroughts’ reported in the paleoclimatic record for Europe, North America, and Australia (Jansen et al., 2007). Recent studies extend this observation to African and Indian droughts (Sinha et al., 2007; Shanahan et al., 2009): much more severe and longer droughts occurred in the past centuries with widespread ecological, political, and socioeconomic consequences. Overall, these studies confirm that in the last millennium several extreme droughts have occurred (Breda and Badeau, 2008; Kallis, 2008; Büntgen et al., 2010).

In North America, there is *medium confidence* that there has been an overall slight tendency toward less dryness (wetting trend with more soil moisture and runoff; Table 3-2), although analyses for some subregions also indicate tendencies toward increasing dryness. This assessment is based on several lines of evidence, including simulations with different hydrological models as well as PDSI and CDD estimates (Alexander et al., 2006; Andreadis and Lettenmaier, 2006; van der Schrier et al., 2006a; Kunkel et al., 2008; Sheffield and Wood, 2008a; Dai, 2011).

The most severe droughts in the 20th century have occurred in the 1930s and 1950s, where the 1930s Dust Bowl was most intense and the 1950s drought most persistent (Andreadis et al., 2005) in the United States, while in Mexico the 1950s and late 1990s were the driest periods. Recent regional trends toward more severe drought conditions were identified over southern and western Canada, Alaska, and Mexico, with subregional exceptions (Dai, 2011).

SREX (p. 172)

Overall, though new studies have furthered the understanding of the mechanisms leading to drought, there is still relatively limited evidence to provide an attribution of observed changes, in particular given the issues associated with the availability of observational data (Section 3.2.1) and the definition and computation of drought indicators (Box 3-3). This latter point was mostly identified in post-AR4 studies (Box 3-3). Moreover, regions where consistent increases in drought are identified (see ‘Observed Changes’) are only partly consistent with those where projections indicate an enhancement of drought conditions in coming decades (see next paragraphs). We thus assess that there is *medium confidence* (see also Section 3.1.5) that anthropogenic influence has contributed to some changes in the drought patterns observed in the second half of the 20th century, based on its attributed impact on precipitation and temperature changes (though temperature can only be indirectly related to drought trends; see Box 3-3). However **there is *low confidence* in the attribution of changes in droughts at the level of individual regions.**

AR5 (pp. 214-215)

Based on evidence since AR4, SREX concluded that there were not enough direct observations of dryness to suggest high confidence in observed trends globally, although there was *medium*

confidence that since the 1950s some regions of the world have experienced more intense and longer droughts. The differences between AR4 and SREX are due primarily to analyses post-AR4, differences in how both assessments considered drought and updated IPCC uncertainty guidance.

Because drought is a complex variable and can at best be incompletely represented by commonly used drought indices, discrepancies in the interpretation of changes can result. For example, Sheffield and Wood (2008) found decreasing trends in the duration, intensity and severity of drought globally. Conversely, Dai (2011a,b) found a general global increase in drought, although with substantial regional variation and individual events dominating trend signatures in some regions (e.g., the 1970s prolonged Sahel drought and the 1930s drought in the USA and Canadian Prairies). Studies subsequent to these continue to provide somewhat different conclusions on trends in global droughts and/or dryness since the middle of the 20th century (Sheffield et al., 2012; Dai, 2013; Donat et al., 2013c; van der Schrier et al., 2013).

In summary, the current assessment concludes that there is not enough evidence at present to suggest more than *low confidence* in a global-scale observed trend in drought or dryness (lack of rainfall) since the middle of the 20th century, owing to lack of direct observations, geographical inconsistencies in the trends, and dependencies of inferred trends on the index choice. Based on updated studies, AR4 conclusions regarding global increasing trends in drought since the 1970s were probably overstated. However, it is *likely* that the frequency and intensity of drought has increased in the Mediterranean and West Africa and decreased in central North America and north-west Australia since 1950.

AR6 (Drought, Observed trends, Section 11.6.2, pp. 1573-75)

p. 1573

Strong precipitation deficits have been recorded in recent decades in the Amazon (2005, 2010), south-western China (2009–2010), south-western North America (2011–2014), Australia (1997–2009), California (2014), the middle East (2012–2016), Chile (2010–2015), the Great Horn of Africa (2011), among others (van Dijk et al., 2013; Mann and Gleick, 2015; Rowell et al., 2015; Marengo and Espinoza, 2016; Dai and Zhao, 2017; Garreaud et al., 2017, 2020; Marengo et al., 2017; Brito et al., 2018; Cook et al., 2018). **Global studies generally show no significant trends in SPI time series** (Orlowsky and Seneviratne, 2013; Spinoni et al., 2014), **and in derived drought frequency and severity data** (Spinoni et al., 2019), with very few regional exceptions (Section 11.9 and Figure 11.17).

p. 1574

For AR6 regions, several studies suggest an increase in the frequency and areal extent of soil moisture deficits, with examples in East Asia (Cheng et al., 2015; Y. Qin et al., 2015; Jia et al., 2018), Western and Central Europe (Trnka et al., 2015b), and the Mediterranean (Hanel et al., 2018; Moravec et al., 2019; Markonis et al., 2021). **Nonetheless, some analyses also show no long-term trends in soil drying in some AR6 regions – for example, in Eastern North America (Park Williams et al., 2017) and Central North America** (Seager et al., 2019), as well as in North Eastern Africa (Kew et al., 2021).

There is evidence based on streamflow records of increased hydrological droughts in East Asia (D. Zhang et al., 2018) and southern Africa (Gudmundsson et al., 2019). **In areas of Western and Central Europe and Northern Europe, there is no evidence of changes in**

the severity of hydrological droughts since 1950 based on flow reconstructions (Caillouet et al., 2017; Barker et al., 2019) and observations (Vicente-Serrano et al., 2019). **In North America, depending on the methods, datasets and study periods, there are differences between studies that suggest an increase (Shukla et al., 2015; Udall and Overpeck, 2017) versus a decrease in hydrological drought frequency (Mo and Lettenmaier, 2018), but in general there is strong spatial variability** (Poshtiri and Pal, 2016). Streamflow observation reference networks of near-natural catchments have also been used to isolate the effect of climate trends on hydrological drought trends in a few regions, but these show limited trends in Northern Europe and Western and Central Europe (Stahl et al., 2010; Bard et al., 2015; Harrigan et al., 2018), North America (Dudley et al., 2020) and most of Australia, with the exception of Eastern and Southern Australia (X.S. Zhang et al., 2016).

p. 1575

Few AR6 regions show observed increases in meteorological drought (Section 11.9), mostly in Africa and South America (NES: *high confidence*; WAF, CAF, ESAF, SAM, SWS, SSA, SAS: *medium confidence*); a few others show a decrease (WSB, ESB, NAU, CAU, NEU, CNA: *medium confidence*). There are stronger signals indicating observed increases in agricultural and ecological drought (Section 11.9), which highlights the role of increased [evapotranspiration], driven by increased [Atmospheric Evaporative Demand], for these trends (Sections 11.6.2.3, 11.6.2.5). Past increases in agricultural and ecological droughts are found on all continents and several regions (WAF, CAF, WSAF, ESAF, WCA, ECA, EAS, SAU, MED, WCE, NES: *medium confidence*), while decreases are found only in one AR6 region (NAU: *medium confidence*). The more limited availability of datasets makes it more difficult to assess historical trends in hydrological drought at regional scale (Section 11.9). Increasing (MED: *high confidence*; WAF, EAS, SAU: *medium confidence*) and decreasing (NEU, SES: *medium confidence*) trends in hydrological droughts have only been observed in a few regions.

AR6 on Attribution (p. 1577)

There are only two AR6 regions in which there is at least *medium confidence* that human-induced climate change has contributed to changes in meteorological droughts (Section 11.9). In South-western South America (SSW), there is *medium confidence* that human-induced climate change has contributed to an increase in meteorological droughts (Boisier et al., 2016; Garreaud et al., 2020), while in Northern Europe (NEU), there is *medium confidence* that it has contributed to a decrease in meteorological droughts (Gudmundsson and Seneviratne, 2016) (Section 11.9). **In other AR6 regions, there is inconclusive evidence in the attribution of long-term trends, but a human contribution to single meteorological events or subregional trends has been identified in some instances... In North America, the human influence on precipitation deficits is complex (Wehner et al., 2017), with low confidence in the attribution of long-term changes in meteorological drought in AR6 regions.**

From: Judith Curry [curry.judith@gmail.com]
Sent: 5/7/2025 1:13:56 PM
To: John Christy [climateman60@gmail.com]
CC: Ross McKittrick [ross.mckittrick@gmail.com]; Steve Koonin [steven.koonin@gmail.com]; Roy W. Spencer [roywspencer@hotmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]
Subject: Re: Ch 8 Extreme weather

I just did a quick read, this looks great. I'll leave the editing to Steve and and Roy. John, enjoy your vacation!

On Tue, May 6, 2025 at 6:53 PM John Christy <climateman60@gmail.com> wrote:
All

Here is a cleaned up version of chapter 8 which you will likely not see until 7 May, so that is the date.

My preference is for someone to read the thing and write the summary (8.4) based upon what a fresh set of eyes would conclude. Steve? Roy?

Ross. The panel charts of the individual station precipitation take up a lot of real estate and I think the value per acre is low. Since you calculated 3 statistics for each station, could you craft a bar chart or something to show that result? You would then have 9 charts, one for each of the 3 statistics and one each of the three regions. The nine charts may be panelized and fit on one plot. I know for us it's important for people to see the actual data (which is why I had those colored bar charts - now monochromatic), but it may be overkill for this document.

As to one of the statistics, I believe 3-day totals will be more meaningful and accurate than 1-day totals. I could send you a file of the heaviest 3-day total for each station and each year and you can do the analysis from there.

I especially like the way you parsed the Sidebar and I hope smart people will finally understand that when dealing with climate, our sample is pathetically small from which to draw hard conclusions.

I also enjoyed the added words on LTP. In fact do you have a few sentences that expand that a little to talk about the erratic nature of precipitation (spatial and temporal) in fancy statistical terms which means finding statistical significance in such a variable is a tough job?

I redid the number-of-event bar charts - all one color now.

I reran the Heatwave results to use 6-day periods as did NCA5. NCA5 was slick though. By choosing 1961-90 their background climatology was cold relative to decades before and since, so that results outside of those 30 years would produce a lot of days that exceed the percentile threshold. Then in the urban heatwave website, they started in 1960, assuring a result that more temps would exceed the threshold in post-1990 years.

That's all I've got.

Aloha

John C.

John Christy

Director, Earth System Science Center
Professor, Atmos and Earth Science
Alabama State Climatologist
The University of Alabama in Huntsville
climateman60@gmail.com

On May 6, 2025, at 5:25 PM, John Christy <climateman60@gmail.com> wrote:

Steve

As Ross notes, the precipitation section is simply an update of our 2019 paper. The daily temperature work from the supplemented USHCN records is in a paper under review (but I suspect will have difficulty being accepted). The data are from the official USHCN site with my supplements adding about 10 percent to cover the missing data. There are about 41 million temperatures here, so I added about 4 million. Thus the results are dominated by publically-available data for others to check. If I get the go-ahead for publication, I can put the complete datafiles on a server for anyone to use.

John C.

John Christy
Director, Earth System Science Center
Professor, Atmos and Earth Science
Alabama State Climatologist
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climateman60@gmail.com

On May 6, 2025, at 3:48 PM, Ross McKittrick <ross.mckitrick@gmail.com> wrote:

The underlying analysis is all from John's and my Journal of Hydrology paper for which the code is already online. John updated and expanded the data sets and I ran them through the same code.

On Tue, May 6, 2025 at 4:41 PM Steven Koonin <steven.koonin@gmail.com> wrote:

A thought about the analysis of long-term CONUS data, which as John knows I like very much:

If some (most?) of this work is as-yet unpublished in a peer-reviewed journal, I'd think you've got to make the expanded and in-filled database (and analysis code?) publicly accessible so that the work can be checked. Are you prepared to do that (at least for the "final", if not the "draft")?

SEK

From: Ross McKittrick <ross.mckittrick@gmail.com>

Sent: Tuesday, May 6, 2025 1:05 PM

To: John Christy <climateman60@gmail.com>

Cc: Judith Curry <curry.judith@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>; Steven Koonin <steven.koonin@googlemail.com>

Subject: Re: Ch 8 Extreme weather

Here's another edition of Ch 8 on extremes taking Judy's and John's points into account. The IPCC/NCA review is ported to an Appendix. I added a paragraph about LTP to the intro. I've incorporated the NE data. The bulk of the chapter is John's US temperature and precip data analysis with some additional material on wildfires, drought and TCs. For the US temperature extremes I moved the range figure to come just after the hot/cold extremes count because I think they both make a coherent point namely that the US becoming less extreme because heat events are rising more slowly than cold events are warming. There will still need to be an overall chapter summary but I'm going to move on to other chapters now. I'll put this in the Dropbox.

On Tue, May 6, 2025 at 12:12 PM John Christy <climateman60@gmail.com> wrote:

All

We can fill in without much trouble the change, or lack thereof, of "high impact" weather events (mainly wind and flooding like hurricanes, tornadoes etc) in the CONUS Extreme chapter. The temp and precip metrics are important because they are just long enough to essentially tell us Mother Nature has a mind of her own.

1. I'll look at Ross's version of 8 soon, but my hope was that Ross would translate the statistical remarks into the correct language(eg are their more precise words that chaotic, episodic, stochastic, etc).
2. We have analyses of the CONUS with more complete datasets than the NCA used (recall NCA analyses depended essentially on a small group at NCEI using datasets that (a) were not very consistent in time, (b) could promote alarm and (c) already easy for them to get to. Our datasets have literally hundreds of thousands of manually keyed-in observations for temporal consistency. In other words, this lets people know we can address these issues from soup to nuts - we're not armchair climate scientists ... we can reproduce what they did, but make the analysis more comprehensive to address the questions.

John C.

Sent from my iPhone

On May 6, 2025, at 4:14 AM, Ross McKittrick

<ross.mckittrick@gmail.com> wrote:

Just read your attribution chapter. I hadn't picked up on the gap between IPCC Ch 11 vs Ch 12 language but I see your point that rather than promoting one set of attribution findings we should explain that even within the same AR different authors assessed things differently. One option is to leave Ch 6 where it is but reverse the order of Ch 7 and 8 while retitling the latter as you suggest. That way, having established the extreme weather types for which there are no detectable trends it will more naturally follow that they won't be discussed in the attribution chapter.

On Tue, May 6, 2025 at 9:45 AM Judith Curry <curry.judith@gmail.com> wrote:

Ok, but the summary table (12.12 from AR6) is inconsistent with conclusions in AR6 ch 11 (I point this out in section 6.4 of my attribution chapter).

In my mind, the main point is disagreement and ambiguity I would suggest chapter 8 going before chapter 6, retitling it as US Weather and Climate Extremes, and make it more of a data chapter, not an attribution chapter (I would put table 12.12 in the attribution chapter if you want to include the actual table)

On Tue, May 6, 2025 at 6:39 AM Ross McKittrick <ross.mckitrick@gmail.com> wrote:

I like John's material too which is why I included it and am working on the extended regional analyses. But on this topic people are heavily primed to believe that extreme weather of all kinds is getting worse due to climate change. The assertion shows up everywhere climate change is discussed including in academic papers. I think it is very valuable to show people that neither the IPCC nor the NCA support such this view. We should at least lead off with the summary table. The library of quotes can go to an appendix but I have found in my public speaking that they have considerable persuasive force for most people. We also need to address floods, droughts, hurricane landfalls, tornadoes etc. I don't see any reason to delete all that material.

On Tue, May 6, 2025 at 9:22 AM Judith Curry <curry.judith@gmail.com> wrote:

I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes"

I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable severe weather event.

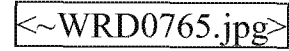
John's version meshes very well with my version of chapter 6. Read especially section 6.4 of my chapter. I note a discrepancy between chapters 11 and 12 in terms of detecting and attributing extreme events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the problems/challenges, and topics that are particularly relevant for the US

On Mon, May 5, 2025 at 7:47 PM Ross McKittrick <ross.mckitrick@gmail.com> wrote:

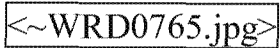
I have wrangled the extreme weather chapter into something I hope flows better and is more readable. I adopted Judy's editorial changes and then the new changes I made are in red. I added some new Figures showing results on PC and SE data and will add the NE chart when I get the data. I also made some

labeling suggestions including for the 3 rainfall charts that are hard to understand. Section summaries and an overall summary are still needed.

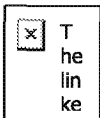
Ross

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Sent: Tuesday, May 6, 2025 10:30 PM
To: Ross McKittrick
Cc: Steve Koonin; Judith Curry; Roy W. Spencer; Travis Fisher
Subject: Re: Ch 8 Extreme weather

Will do. Over and out.

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summary are still needed.

Ross

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<~WRD0765.jpg>

Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2012
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Judith Curry, President
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Reno, NV USA
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<http://www.cfanclimate.net>

From: John Christy [climateman60@gmail.com]
Sent: 5/7/2025 1:53:06 AM
To: Ross McKittrick [ross.mckittrick@gmail.com]
CC: Steve Koonin [steven.koonin@gmail.com]; Judith Curry [curry.judith@gmail.com]; Roy W. Spencer [roywspencer@hotmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]
Subject: Re: Ch 8 Extreme weather
Attachments: Untitled attachment.htm; 8 Extreme weather.JRC.May07.docx; Untitled attachment.htm

All

Here is a cleaned up version of chapter 8 which you will likely not see until 7 May, so that is the date.

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That's all I've got.

Aloha

John C.

John Christy
Director, Earth System Science Center
Professor, Atmos and Earth Science
Alabama State Climatologist
The University of Alabama in Huntsville
climateman60@gmail.com

[08]

> On May 6, 2025, at 5:25 PM, John Christy <climateman60@gmail.com> wrote:

>

> Steve

>

> As Ross notes, the precipitation section is simply an update of our 2019 paper. The daily temperature work from the supplemented USHCN records is in a paper under review (but I suspect will have difficulty being accepted). The data are from the official USHCN site with my supplements adding about 10 percent to cover the missing data. There are about 41 million temperatures here, so I added about 4 million. Thus the results are dominated by publically-available data for others to check. If I get the go-ahead for publication, I can put the complete datafiles on a server for anyone to use.

>

> John C.

>

>

> John Christy

> Director, Earth System Science Center

> Professor, Atmos and Earth Science

> Alabama State Climatologist

> The University of Alabama in Huntsville

> climateman60@gmail.com

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>

>> On May 6, 2025, at 3:48 PM, Ross McKittrick <ross.mckitrick@gmail.com> wrote:

>>

>> The underlying analysis is all from John's and my Journal of Hydrology paper for which the code is already online. John updated and expanded the data sets and I ran them through the same code.

>>

>>

>> On Tue, May 6, 2025 at 4:41 PM Steven Koonin <steven.koonin@gmail.com <<mailto:steven.koonin@gmail.com>>> wrote:

>>> A thought about the analysis of long-term CONUS data, which as John knows I like very much:

>>>

>>>

>>>

>>> If some (most?) of this work is as-yet unpublished in a peer-reviewed journal, I'd think you've got to make the expanded and in-filled database (and analysis code?) publicly accessible so that the work can be checked. Are you prepared to do that (at least for the "final", if not the "draft")?

>>>

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>>> SEK

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>>>

>>> From: Ross McKittrick <ross.mckitrick@gmail.com <<mailto:ross.mckitrick@gmail.com>>>

>>> Sent: Tuesday, May 6, 2025 1:05 PM

>>> To: John Christy <climateman60@gmail.com <<mailto:climateman60@gmail.com>>>

>>> Cc: Judith Curry <curry.judith@gmail.com <<mailto:curry.judith@gmail.com>>>; Roy W. Spencer <roywspencer@hotmail.com <<mailto:roywspencer@hotmail.com>>>; Travis Fisher <travis.scott.fisher@gmail.com <<mailto:travis.scott.fisher@gmail.com>>>;

>>> Steven Koonin <steven.koonin@googlemail.com <<mailto:steven.koonin@googlemail.com>>>

>>> Subject: Re: Ch 8 Extreme weather

>>>

>>>

>>>

>>> Here's another edition of Ch 8 on extremes taking Judy's and John's points into account. The IPCC/NCA review is ported to an Appendix. I added a paragraph about LTP to the intro. I've incorporated the NE data. The bulk of the chapter is John's US temperature and precip data analysis with some additional material on wildfires, drought and TCs. For the US temperature extremes I moved the range figure to come just after the hot/cold extremes count because I think they both make a coherent point namely that the US becoming less extreme because heat events are rising more slowly than cold events are warming. There will still need to be an overall chapter summary but I'm going to move on to other chapters now. I'll put this in the Dropbox.

>>>

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>>> On Tue, May 6, 2025 at 12:12 PM John Christy <climateman60@gmail.com <<mailto:climateman60@gmail.com>>> wrote:

>>>
>>> All
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>>>
>>> We can fill in without much trouble the change, or lack thereof, of “high impact” weather events (mainly wind and flooding like hurricanes, tornadoes etc) in the CONUS Extreme chapter. The temp and precip metrics are important because they are just long enough to essentially tell us Mother Nature has a mind of her own.
>>>
>>>
>>>
>>> 1. I’ll look at Ross’s version of 8 soon, but my hope was that Ross would translate the statistical remarks into the correct language (eg are their more precise words that chaotic, episodic, stochastic, etc).
>>>
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>>> 2. We have analyses of the CONUS with more complete datasets than the NCA used (recall NCA analyses depended essentially on a small group at NCEI using datasets that (a) were not very consistent in time, (b) could promote alarm and (c) already easy for them to get to. Our datasets have literally hundreds of thousands of manually keyed-in observations for temporal consistency. In other words, this lets people know we can address these issues from soup to nuts - we’re not armchair climate scientists ... we can reproduce what they did, but make the analysis more comprehensive to address the questions.
>>>
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>>> John C.
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>>> Sent from my iPhone
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>>> On May 6, 2025, at 4:14 AM, Ross McKittrick
>>>
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>>> <ross.mckittrick@gmail.com <<mailto:ross.mckittrick@gmail.com>>> wrote:
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>>> Just read your attribution chapter. I hadn’t picked up on the gap between IPCC Ch 11 vs Ch 12 language but i see your point that rather than promoting one set of attribution findings we should explain that even within the same AR different authors assessed things differently. One option is to leave Ch 6 where it is but reverse the order of Ch 7 and 8 while retitling the latter as you suggest. That way, having established the extreme weather types for which there are no detectable trends it will more naturally follow that they won’t be discussed in the attribution chapter.
>>>
>>>
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>>> On Tue, May 6, 2025 at 9:45 AM Judith Curry <curry.judith@gmail.com <<mailto:curry.judith@gmail.com>>> wrote:
>>>
>>> Ok, but the summary table (12.12 from AR6) is inconsistent with conclusions in AR6 ch 11 (I point this out in section 6.4 of my attribution chapter).
>>>
>>>
>>>
>>> In my mind, the main point is disagreement and ambiguity I would suggest chapter 8 going before chapter 6, retitling it as US

Weather and Climate Extremes, and make it more of a data chapter, not an attribution chapter (I would put table 12.12 in the attribution chapter if you want to include the actual table)

>>>

>>>

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>>> On Tue, May 6, 2025 at 6:39 AM Ross McKittrick <ross.mckittrick@gmail.com <<mailto:ross.mckittrick@gmail.com>>> wrote:

>>>

>>> I like John's material too which is why I included it and am working on the extended regional analyses. But on this topic people are heavily primed to believe that extreme weather of all kinds is getting worse due to climate change. The assertion shows up everywhere climate change is discussed including in academic papers. I think it is very valuable to show people that neither the IPCC nor the NCA support such this view. We should at least lead off with the summary table. The library of quotes can go to an appendix but I have found in my public speaking that they have considerable persuasive force for most people. We also need to address floods, droughts, hurricane landfalls, tornadoes etc. I don't see any reason to delete all that material.

>>>

>>>

>>>

>>> On Tue, May 6, 2025 at 9:22 AM Judith Curry <curry.judith@gmail.com <<mailto:curry.judith@gmail.com>>> wrote:

>>>

>>> I actually liked John's chapter. I would have retitled it "US temperature and rainfall extremes"

>>>

>>> I think this is more relevant than a complete rehash of everything the last 3 IPCC reports have stated for every conceivable severe weather event.

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>>> John's version meshes very well with my version of chapter 6. Read especially section 6.4 of my chapter. I note a discrepancy between chapters 11 and 12 in terms of detecting and attributing extreme events. This is the main point in my opinion, there is ambiguity in all this. Lets focus on pointing out the problems/challenges, and topics that are particularly relevant for the US

>>>

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>>> On Mon, May 5, 2025 at 7:47 PM Ross McKittrick <ross.mckittrick@gmail.com <<mailto:ross.mckittrick@gmail.com>>> wrote:

>>>

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>>>

>>> Ross

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>>> <~WRD0765.jpg>

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>>> Judith Curry, President

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>>> <http://www.cfanclimate.n> <<http://www.cfanclimate.com>>et

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Aloha

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8 Extreme weather in the US and elsewhere

8.1 Introduction

Weather extremes, usually related to temperature and/or precipitation, often disrupt infrastructure and therefore human health and thriveability. Indeed, the ability of any surface-dwelling species to live productively is somewhat constrained by these extremes which in essence create the bounding limits for survival. The issue here is whether these extremes, and their attendant potential danger, may be changing and if so whether the change is in response to increases in infrared-absorbing greenhouse gases (GHGs) (e.g., IPCC AR6 Seneviratne et al. 2021).

Unfortunately, the sample of time from which we are able to quantitatively analyze variations in extreme events is quite brief, around 130 years. This period certainly does not begin to contain all of the extreme events that the climate system is able to create naturally. Over geologic time the climate system has generated an (essentially) infinite variety of patterns and extremes which humans have never observed, and thus do not enter our databases from which extreme statistics are determined [see *Perils of short data records* below]. Thus, assuming that a climate pattern or event hitherto not experienced in our lifetime must therefore be the result of enhanced GHG concentrations requires the assumption that natural variations are insignificant.

This is especially true for precipitation events. The hydrological literature has long noted the phenomenon of *Long Term Persistence* (LTP) in rainfall data (Hurst 1951, Cohn and Lins 2005, Markonis and Koutsoyiannis 2015). LTP has a formal mathematical definition but it can be thought of intuitively as the presence of natural variations with strong autocorrelation properties that result in cycle-like behavior on long time scales. The presence of LTP requires very long data samples to obtain accurate estimates of variance; analysis of data samples that are short relative to the LTP scale will tend to yield underestimated variances which in turn yields overstated significance of apparent trends and underestimation of the likelihood of extreme events (Cohn and Lins 2005).

With this caveat in mind we examine the evidence for changes in weather and climate extremes. It has become routine in media discussions, government and private sector discussions and even in some academic literature to make generalized assertions that extreme weather of all types is getting worse due to GHGs and climate change. Yet expert assessments have not typically drawn such sweeping conclusions and instead have emphasized the difficulty both of identifying specific trends and establishing a causal connection with anthropogenic forcing. In the Appendix to this chapter we provide excerpts of these findings from previous IPCC and NCA assessments.

8.2 Global and continental indicators of extreme weather trends

8.2.1 Tropical Cyclones (TCs)

Hurricane strength records for the North Atlantic and the Western Pacific go back to 1950 and the record does not show an increase in either total or major TCs. Figure 8.1 was published by Roger Pielke Jr. as an update to the Best Track data series originally presented in Weinkle et al. (2012).

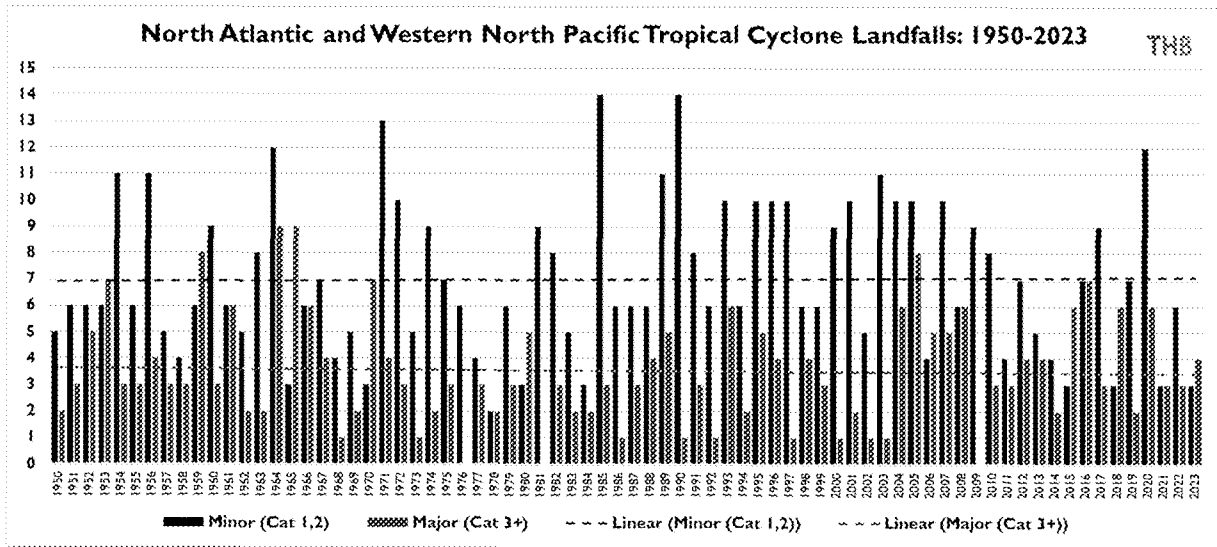


Figure 8.1. Tropical Cyclone Landfalls. Source: <https://rogerpielkejr.substack.com/p/global-tropical-cyclones>, Weinkle et al. (2012)

After 1980, as shown in Figure 8.2, which reproduces data from the Climate Atlas of Dr. Ryan Maue neither the total number of hurricanes nor the frequency of major ones have become more common since 1980, indeed both have trended down since the 1990s:

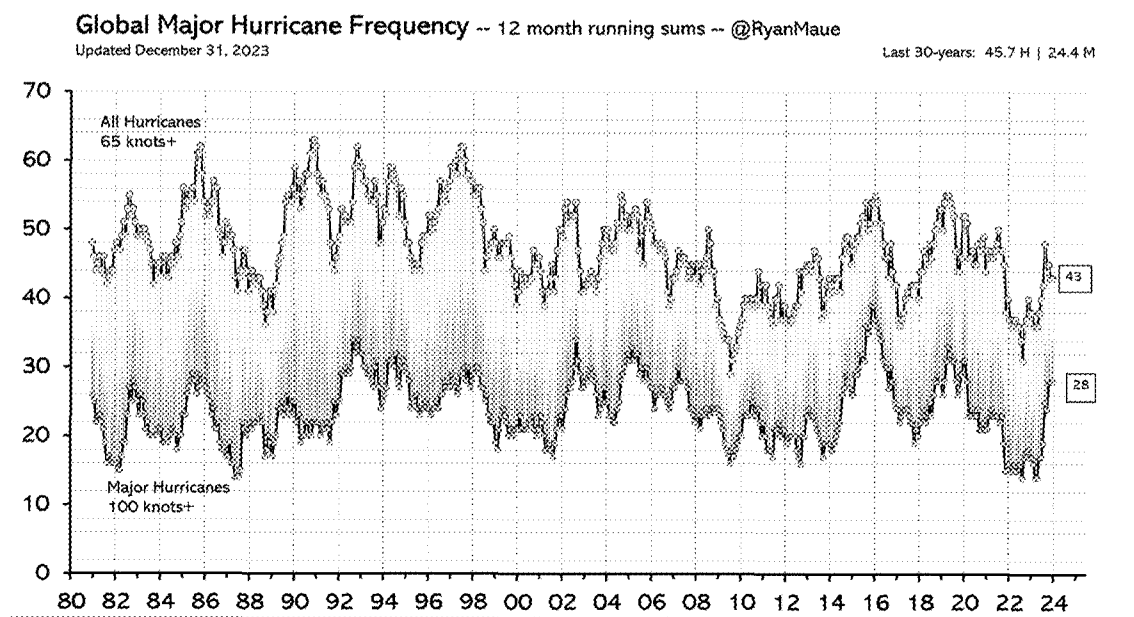


Figure 8.2: Global hurricane frequency. Source: Maue (2024)

A metric that combines the number and frequency of TCs is the Accumulated Cyclone Energy or ACE Index maintained at Colorado State University, shown in Figure 8.3.

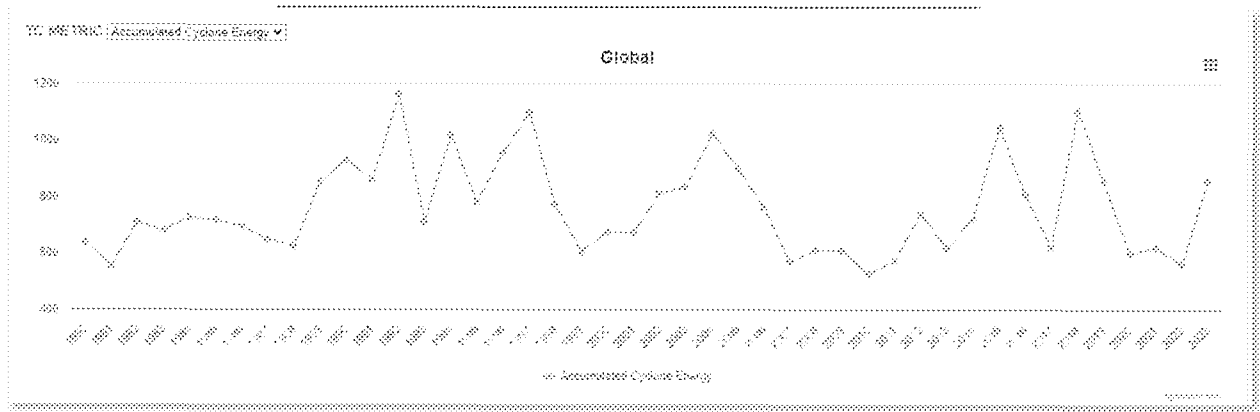


Figure 8.3: Global Accumulated Cyclone Energy. Source: Klotzbach (2025)
<https://tropical.atmos.colostate.edu/Realtime/index.php?arch&loc=global>

As is clear, it is also not increasing and since 1990 has declined slightly.

Climate models project declining hurricane formation rates in a warming climate (Chand et al. 2022). Climate models also project fewer Tropical Cyclones under future global warming, and even though models project they will increase in strength, the annual averages of rainfall maxima decline (Stansfield et al. 2020). Note that Tu et al. (2024) report that the Power Dissipation Index (PDI), a measure of the destructiveness of hurricanes, has either remained unchanged or has declined in all global oceanic basins since the mid-1990s.

8.2.2 Wildfires

As shown in Figures 8.4 and 8.5 global wildfire activity as measured by European Space Agency peaked over a decade ago and shows a downward trend since.

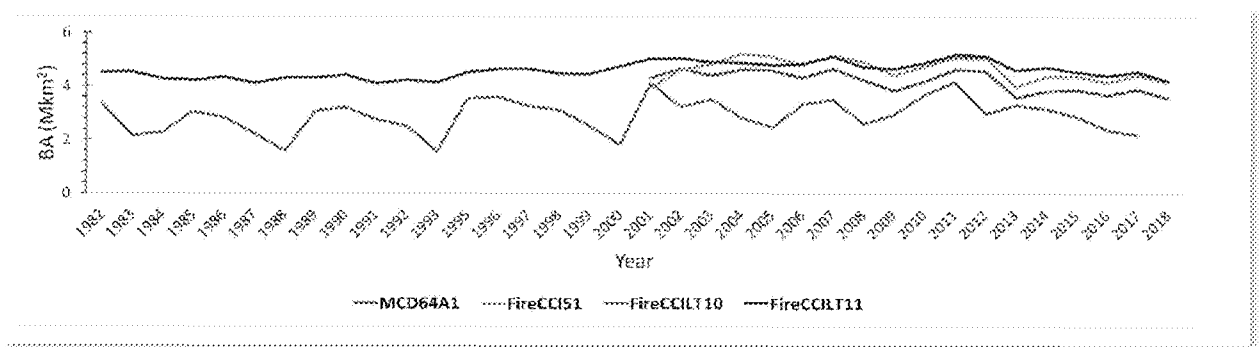


Figure 8.4: Global wildfire 1982-2018. Source: Copied from Oton et al. (2021). Note: the different coloured lines represent different data products based on satellites and algorithms used.

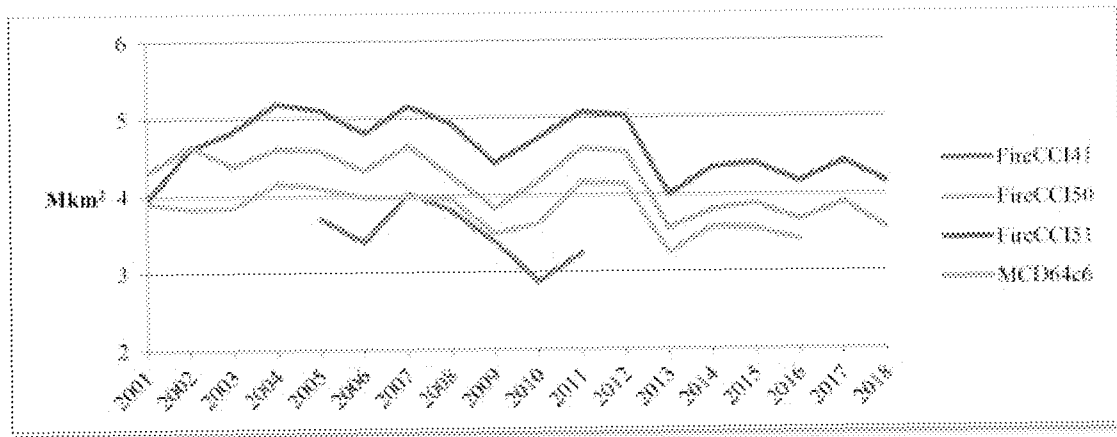


Figure 8.5: Global wildfire 2001-2018. Source: Copied from Lizundia-Loiola et al. (2021). Note: the different coloured lines represent different data products based on satellites and algorithms used

US data from the National Interagency Fire Centre (NIFC) from 1926 to 2023 are shown in Figure 8.6.

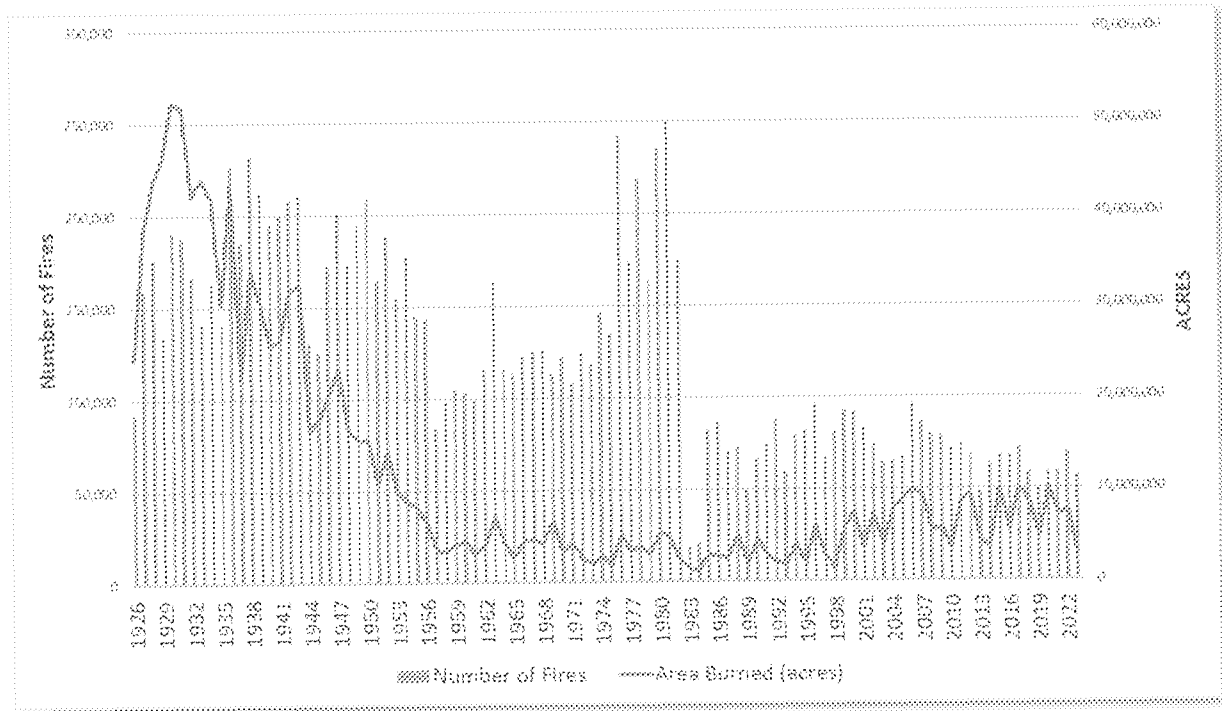


Figure 8.6: US wildfires 1926 to 2023. Source: National InterAgency Fire Centre data Pre-2017 (archived)

https://web.archive.org/web/20200212033452/https://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html. 2018-2023: <https://www.nifc.gov/fire-information/statistics/wildfires>

Note the NIFC has removed the pre-1960 data from its current website. They claim it is because measurement methods changed after 1960. This explanation seems inadequate since agencies blend temperature and extreme weather data series in other context when measurement systems changed. In this case if anything the measurement of wildfires has improved since the early 20th century so any bias will be towards understating early wildfire counts. Nonetheless just focusing on the post-

1985 interval the number of fires is not increasing. The area burned did increase but only until about 2007.

It is difficult to establish a natural baseline for wildfire activity because of active fire suppression activity since 1900. Paleoclimatic evidence indicates, however, that past wildfire activity was much higher than at present. Marlon et al. (2012) used sedimentary charcoal layers to reconstruct fire history of western US for the past 1400 years. They also fit a model to predict expected fire activity as a function of climatic conditions. The results are summarized in Figure 8.7 below (from Figure 2 in their paper).

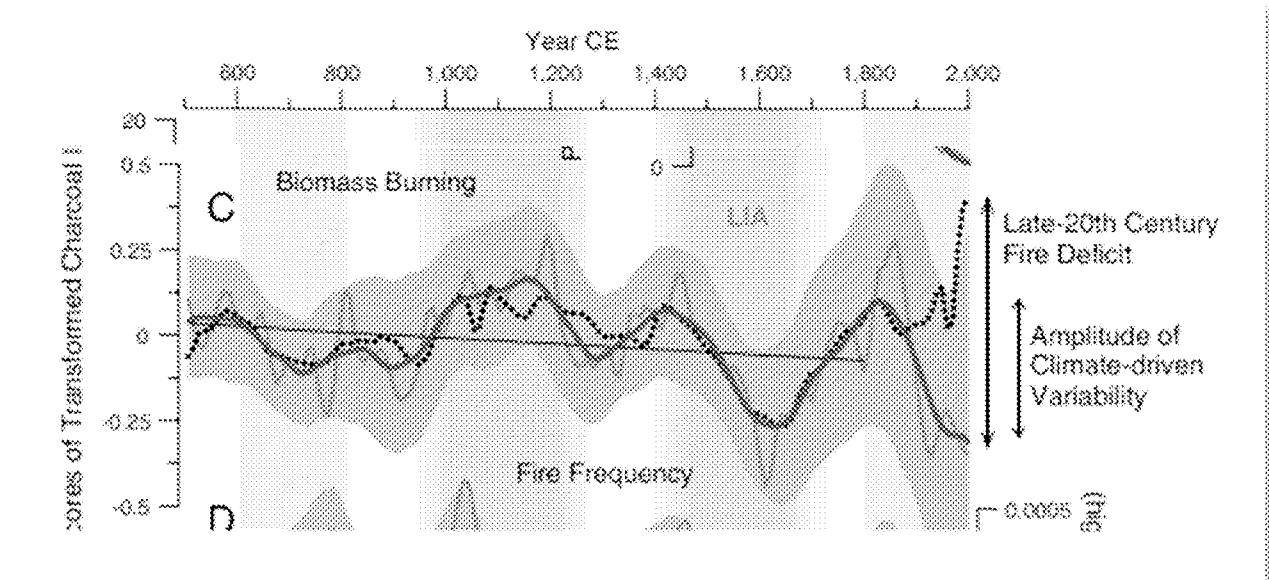


Figure 8.7: Fire frequency and fire deficit in the US. Source: Copied from Marlon et al. (2012)

In their figure the red line shows the smoothed charcoal record and the black dotted line shows the predicted charcoal record based on the statistical model. The gap at the end implies there has been a growing wildfire deficit over the 20th century. In other words, however much fire was observed in the 20th century it was less than what would have been observed in previous centuries based on the climatic conditions. Parks et al. (2025) likewise find that despite the recent increase in wildfire burn area in North America, relative to historical wildfire regimes there remains a significant wildfire deficit.

8.2.3 Precipitation

Figure 8.8 shows that US long term data from NOAA shows an insignificantly increasing tendency toward extreme wetness (+0.001% per year)

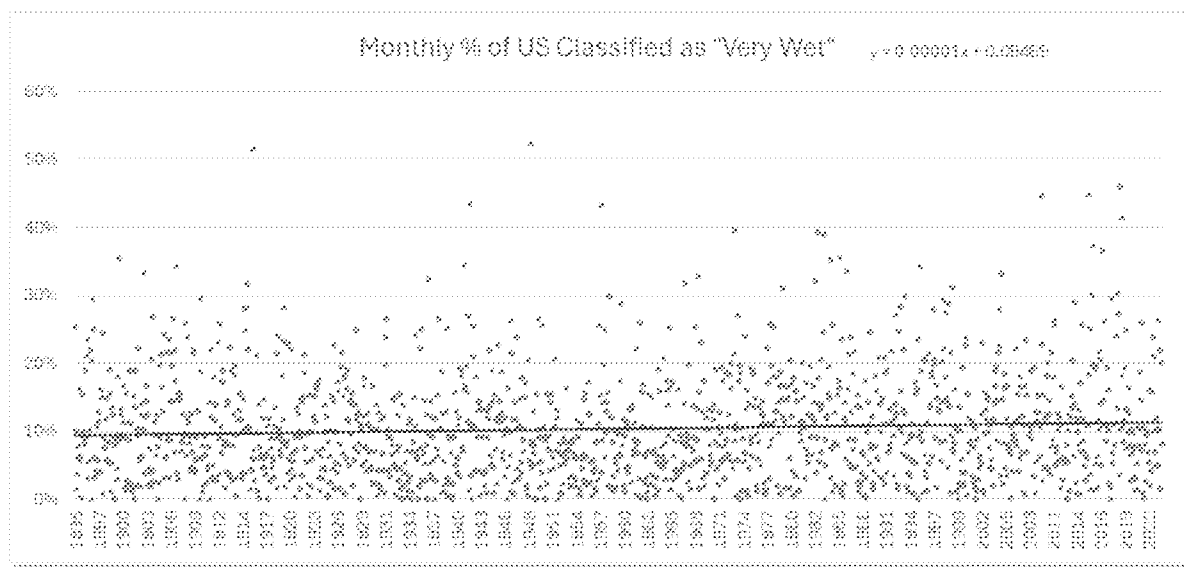


Figure 8.8: Long term US wetness (%). Source: NOAA
<https://www.ncei.noaa.gov/access/monitoring/uspa/wet-dry/0>

Precipitation will be discussed further in the review of CONUS data below.

8.2.4 Drought

As shown in Figure 8.9 US long term data (NOAA) shows an insignificantly declining tendency toward extreme dryness (-0.001% per year)

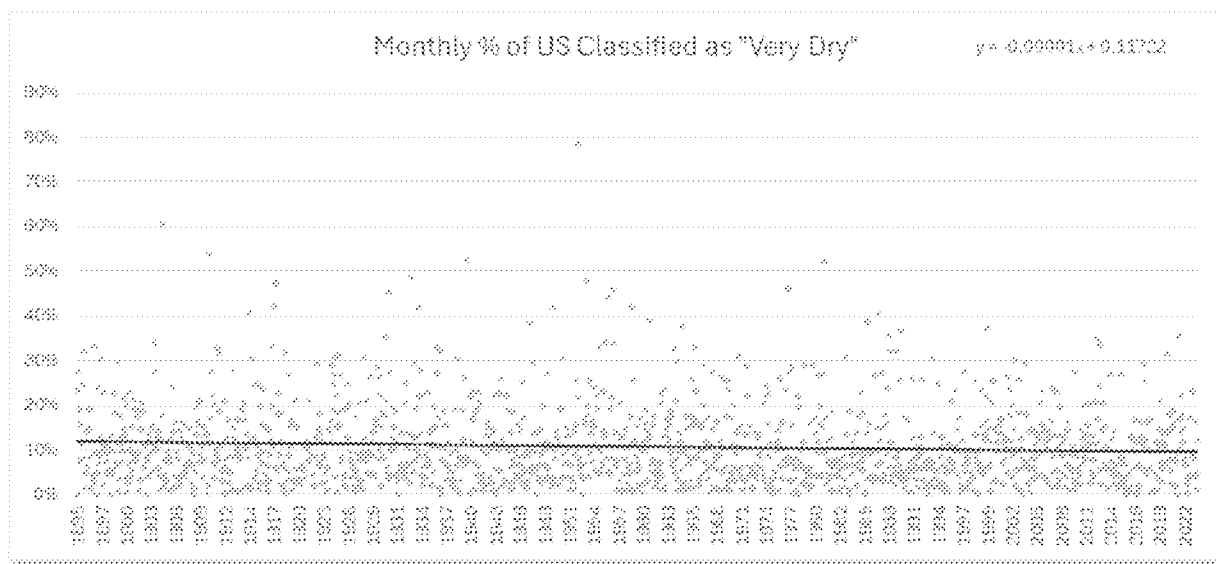


Figure 8.9: US dryness (%) 1895—2023. Source: NOAA
<https://www.ncei.noaa.gov/access/monitoring/uspa/wet-dry/0>

Kogan et al. (2020) examines a 38-year high-resolution satellite-based drought measure and concludes that global drought has not intensified and is not connected to climate change: “it is possible to state firmly that global and main grain countries’ drought area and intensity trends have not been following global climate warming since 1980’s.”

8.3 Analysis of Conterminous US (CONUS) data on temperature and precipitation extremes

8.3.1 CONUS daily temperatures are becoming less extreme

Daily maximum temperatures in the warm season (TMax, May-Sep) and daily minimum temperatures in the cold season (TMin, Dec-Mar) are available beginning in Dec 1898 (126 years). The dataset consists of 1,211 CONUS stations designated as United States Historical Climate Network or USHCN stations (Quinlan et al. 1987, Karl et al. 1990). These stations were selected by NOAA as having the fewest problematic issues with gaps, station moves and instrument changes. Where gaps still exist, nearby stations (bias-corrected) were merged so that the median volume of data available for a station is 98%. Although errors certainly reside in the dataset, with over 1,000 stations any underlying signal we discover-can be characterized by relatively high confidence.

We begin with the question of whether the occurrence of daily record high or low temperatures changed has changed since Dec 1898. Each warm-season has 153 days (1 May to 30 Sep) and each cold-season has 122 days (1 Dec to 31 Mar). For each station we calculated the year in which the record highest (lowest) temperature occurred. With 126 years of observations, if there were no temperature trends over time-the expected number of records for TMax would be 1.21 per year and for TMin 0.96 per year. Figure 8.10 indicates the observed distribution in time of the occurrence of these extreme events.

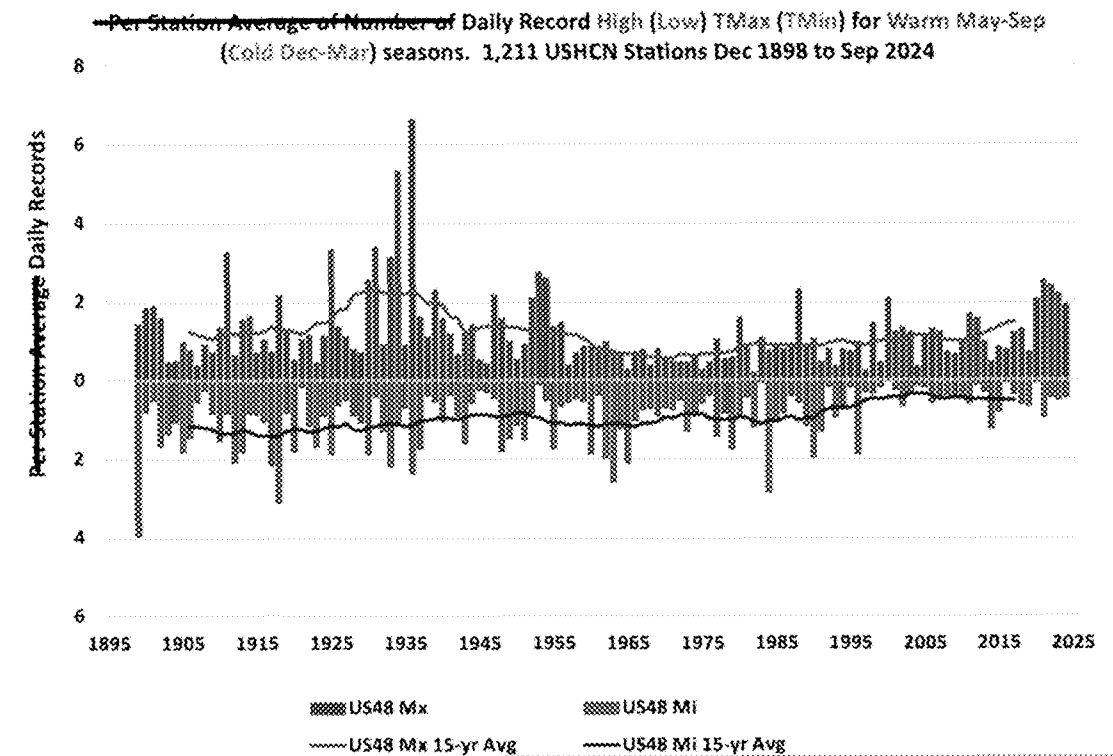


Figure 8.10 Number of daily record High (red) and Low (blue) for warm and cold seasons in the CONUS. The lines represent 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92% of observations in the 126-year period since Dec 1898.

The results indicate a common feature in many metrics of warm-season extremes in the CONUS - the exceptional heat of the 1920s and especially the 1930s peaking in 1936. On a per-station average, 60% of the TMax records and 59% of the TMin records occurred in the first half of the period (1899-1961).

On the cold side, the Valentine's Day Arctic outbreak in Feb 1899 stands as the most extensive cold extreme experienced by the CONUS, with 1917 2nd. The frequency of cold records has declined, especially over the last quarter of the period in which only 13% of the extreme cold events were measured. In contrast, 25% of the extreme TMax records were achieved in the last quarter in accordance with statistical expectations. These general features have been noted in past assessments (IPCC AR5, IPCC AR6, NCA4, NCA5). Combining the two records the overall reduction in numbers of both cold and hot extremes over the past century indicates a climate less prone to extremes.

This pattern is also shown in Figure 8.11. For each station and for each year the hottest warm season and coldest cold-season temperatures were calculated and converted to anomalies relative to the station's long term warm and cold season (respectively) averages. Then the differences between these were computed by station and geographically-averaged over all stations, thus yielding an annual measure of the expected range of local extreme temperatures for each year. Figure 8.11 shows the 15-year trailing average of this measure which has clearly declined over the past century.

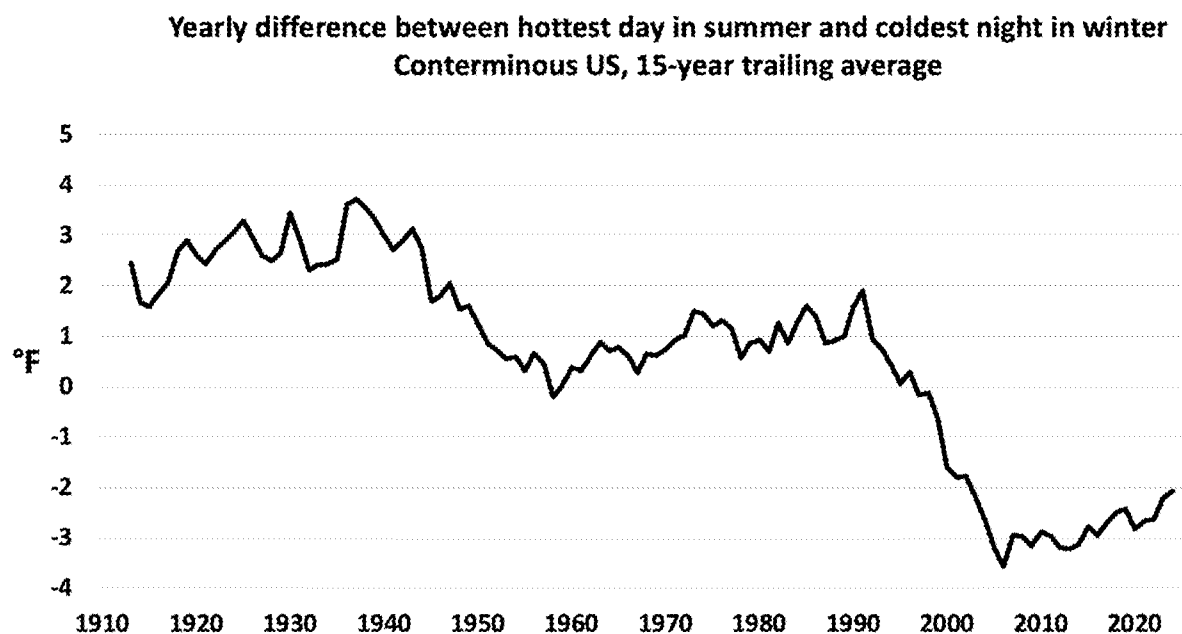


Figure 8.11. 15-year trailing average of the difference each year of each station’s hottest warm-season TMax and coldest cold-season TMin relative to the long-term average.

The average difference for each station between the hottest summer TMax and coldest winter TMin has declined about 5°F in the past 126 years. The decline is due mostly to warming winter TMin, but a decline in the magnitude of summer TMax is also a factor. The rise in TMin has been strongly related to the growing presence of manufactured surfaces around the weather stations over the last 100+ years (Spencer et al. 2025).

Summarizing Figures 8.10 and 8.11, while temperature extremes are regularly experienced in the US and attract a great deal of media attention, long term records show the US climate has become less extreme over time when measured in terms of the range between warm season maxima and cold season minima.

8.3.2 Exceedances of a heat threshold

Under the heading of “The Risk of Temperature Extremes is Changing”, the most recent US National Climate Assessment report (NCA5) notes the increase in a threshold metric of number of days at or above 95°F, stating,

“The western US has been particularly affected by extreme heat since the 1980s ..., experiencing a larger increase in days over 95°F, as would be expected given the greater warming in that region relative to the eastern US. Several major heatwaves have affected the US since 2018, including a record-shattering event in the Pacific Northwest in 2021.”

Are the occurrences of 95°F days changing? In a climate as varied as that of CONUS, threshold statistics can be misleading. A region with many stations which have near 95°F TMax average

temperatures in the summer might see large swings in the metric when only small changes in average temperature occur. Elsewhere with stations that either rarely or virtually always achieve 95°F TMax temperatures, a small change will not impact the results much at all. In the past 126 years, the average CONUS station experienced 129 days exceeding 95°C per 6-yr period, but the regional values range from 278 in the Southern Plains to 9 in the Northeast. Thus, one needs to view such threshold analyses with caution.

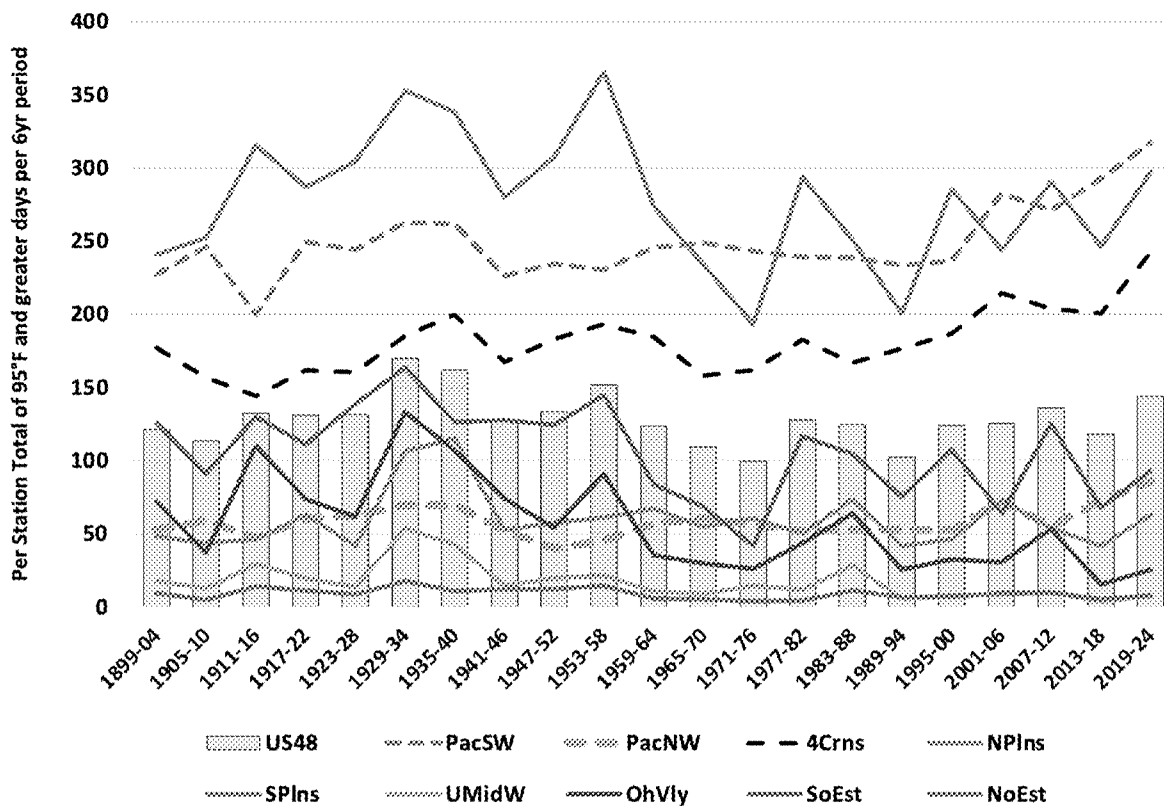


Figure 8.12. Total number of days $\geq 95^{\circ}\text{F}$ in 6-yr periods, US 48 (bars) and regions (lines).

In Fig. 8.12 we see that only three of the nine regions, all in the West, have experienced upward trends in the number of 95°F or hotter days (dashed lines). The CONUS as a whole has not and the other six regions have experienced declines.

The Pacific NW heatwave of 2021 is referenced as supportive information for the NCA5 claim, an event examined more closely in section 6.4. The evidence indicates it was a “black swan” event, i.e. a single, unprecedented event in the existing record suggesting it is not indicative of a pattern of increasing extreme heat. For example, the 5-day average tropospheric grid-point temperature anomaly over the Pacific NW was +10.8 C, the most extreme NH grid point summer anomaly in the 46 years from over 4 million grids. In contrast, the global anomaly was virtually zero (+0.03 C, Mass et al. 2024).

The heading “The Risk of Temperature Extremes is Changing” suggests positive trends are now being observed in threshold temperatures on a widespread basis, but that is not evidenced in the combined CONUS results of the figures above.

8.3.3 Heatwaves

Of more impact than a single daily record is the phenomena of heatwaves, or consecutive days which exceed an extreme threshold. For this study, the metric will be the number of “Heatwave Days” defined as the sum of all days in May-Sep each year which exceed the 90th percentile that occur within consecutive periods of at least six days in length. This is equivalent to the method in NCA5 except the reference period here is the entire record 1899-2024 while NCA5 limited the reference period to 1961-1990, a cool episode. By selecting 1961-1990, the occurrence of positive results (days exceeding the 90th percentile) will be enhanced in periods warmer than the reference base, especially if starting in 1960 and moving to the present (see *Urban Influences* below).

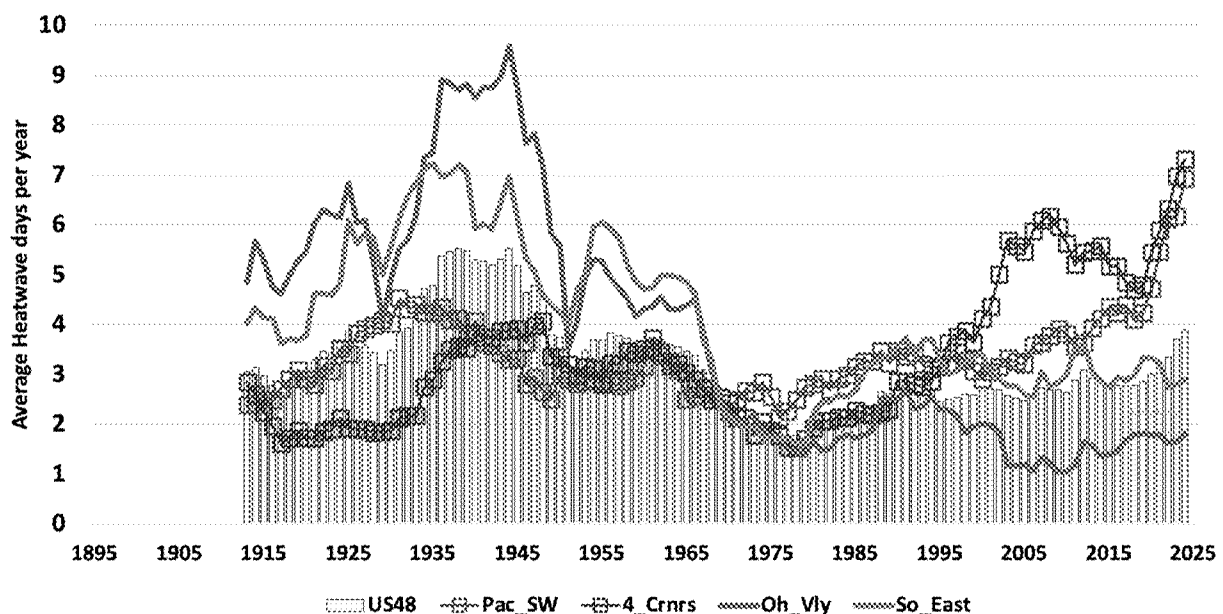


Figure 8.13 15-year trailing average of number of heatwave days per year per station in the CONUS (bars) and four regions: Pac_SW (purple squares, CA, NV), 4_Crnrs (red squares, AZ,NM,UT,CO), Oh_Vly (blue, MO, IL, KY, TN, IN, OH, WV) and So_East (green, MS, AL, GA, FL, SC, NC, VA).

Figure 8.13 indicates again the excessive heat of the first half of the 20th century, primarily in the eastern two-thirds of the nation, as seen in the regional values for the Ohio Valley and the Southeast as examples. The West has seen a recent increase of heatwave days and the two regions with the highest number are shown, the Pacific Southwest and the Four-Corners (NCA5). This indicates that the background warm season circulation favored heatwaves in the eastern portions of the country in the first half of the 20th century, but in the 21st century the patterns have favored heatwaves in the West.

Of interest here is the regional variation of this metric. The four northern regions (Pacific NW, Northern Plains, Upper Midwest, and Northeast) on average experience 15 to 27 heatwave days per 15-year period. In contrast, the five southern regions (Pacific Southwest, 4-Corners, Southern Plains,

Ohio Valley and Southeast) see 37 to 54 such days, essentially twice as many. This suggests the summer circulation pattern is more prone to stationary events in the southern regions while transient systems in the northern regions are more common and thus cut short these potentially longer events.

Urban influences

The NCA5 directs readers to the website <https://www.globalchange.gov/indicators/heat-waves> (USGCRP 2023) to view the number of urban heatwaves by decade from the 1960s. The figure reveals a monotonic increase in each decade from 2 occurrences per year in the 1960s to 6 in the 2020s. The definition of a heatwave is unusual but practical from a human discomfort perspective - a period of at least 2 consecutive days when the apparent minimum temperature (combination of temperature and humidity) exceeds the 85th percentile. Note too, the dataset is limited to the 50 largest cities in the US.

These increasing values since 1960 presented in USGCRP (2023) are entirely reasonable, but for at least two reasons unrelated to GHG emissions. Urbanization in these cities is a major factor in the rise of TMin relative to co-located TMax and relative to TMin at rural stations. Also, the 1960s was the coldest decade and 1970s the second coldest decade since the 1910's, so this starting date preconditions the time series to show increases. This does not dismiss the real rise in nighttime temperatures in major US cities and the societal impacts associated with these changes. However, we note for a variety of reasons, that summer TMax (especially in rural areas) serves as better response variable for detecting potential changes in heatwaves influenced by changes in the background climate due, for example, to increasing GHGs (Christy et al. 2009). For the CONUS as a whole, the evidence in this section suggests GHG emissions have had little-to-no effect on heatwaves in the CONUS.

8.3.4 Extremes in daily precipitation.

Due to its stochastic and episodic character, precipitation requires careful statistical treatment to understand variability over long time periods (see *8.1 Introduction*). The US National Climate Assessments (NCA4, NCA5) have highlighted an increase in the occurrence of the heaviest precipitation events (defined in different ways) primarily in the eastern half of the CONUS, especially the Northeast, when starting in either 1901 or 1958. Interestingly, the regional variations indicate that the largest increases in extreme events are in the Northeast and least in the West, which is counter to the changes in temperature extremes shown above.

McKittrick and Christy (2019) examined long-term and consistent station observations of daily precipitation to test some of these NCA claims for the Southeast and West Coast. In neither case when the time series were extended back in time (as far as 1872 in some cases) or when starting later (1978) were the trends significant. For this report we update these findings with similarly constructed observations from 29 stations on the Pacific Coast (1893ff from San Diego CA to Blaine WA, see Figure 8.14), 24 stations in the humid Southeast (1872ff from Austin TX to Washington DC, see Figure 8.15), and 21 stations in the Northeast (1888ff from Buffalo NY to Gardiner ME, see Figure 8.16).

In the Pacific region, over the whole sample, the trend in average precipitation is negative and significant in Astoria and insignificant elsewhere. The trend in rainfall variance is positive and significant in Big Sur and insignificant elsewhere. The trend in daily maximum precipitation is positive and significant in Aberdeen and Big Sur and negative and significant in Newport and

insignificant elsewhere. Averaged over all stations in the region none of these three trend parameters is statistically significant.

In the Southeast region over the whole sample the trend in average precipitation is positive and significant only in Mobile and Quitman, the trend in rainfall variance is positive and significant only in Mobile and the trend in daily maximum precipitation is positive and significant only in Vicksburg and Norfolk. Averaged over all stations in the region none of these three trend parameters is statistically significant.

The Northeast region exhibits a pattern of increasing average rainfall. The trend in average precipitation is positive and significant in 9 of 21 locations and in the region averaged overall. The trend in rainfall variance is positive and significant only in Portland, Albany and Buffalo and insignificant elsewhere and not in the regional average. The trend in daily maximum precipitation is positive and significant only in Portland ME and Gardiner ME and insignificant elsewhere and not in the regional average.

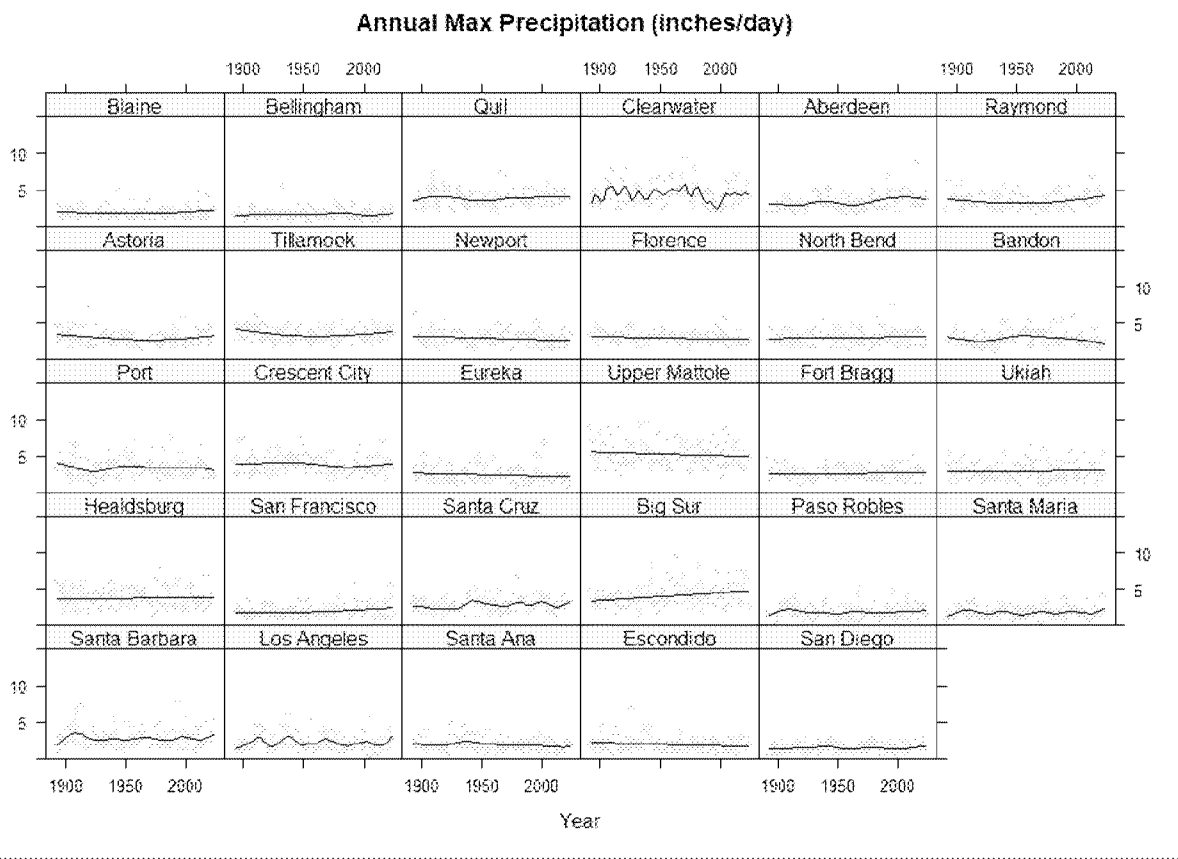


Figure 8.11 Annual maximum precipitation for 29 Pacific stations 1893 to present

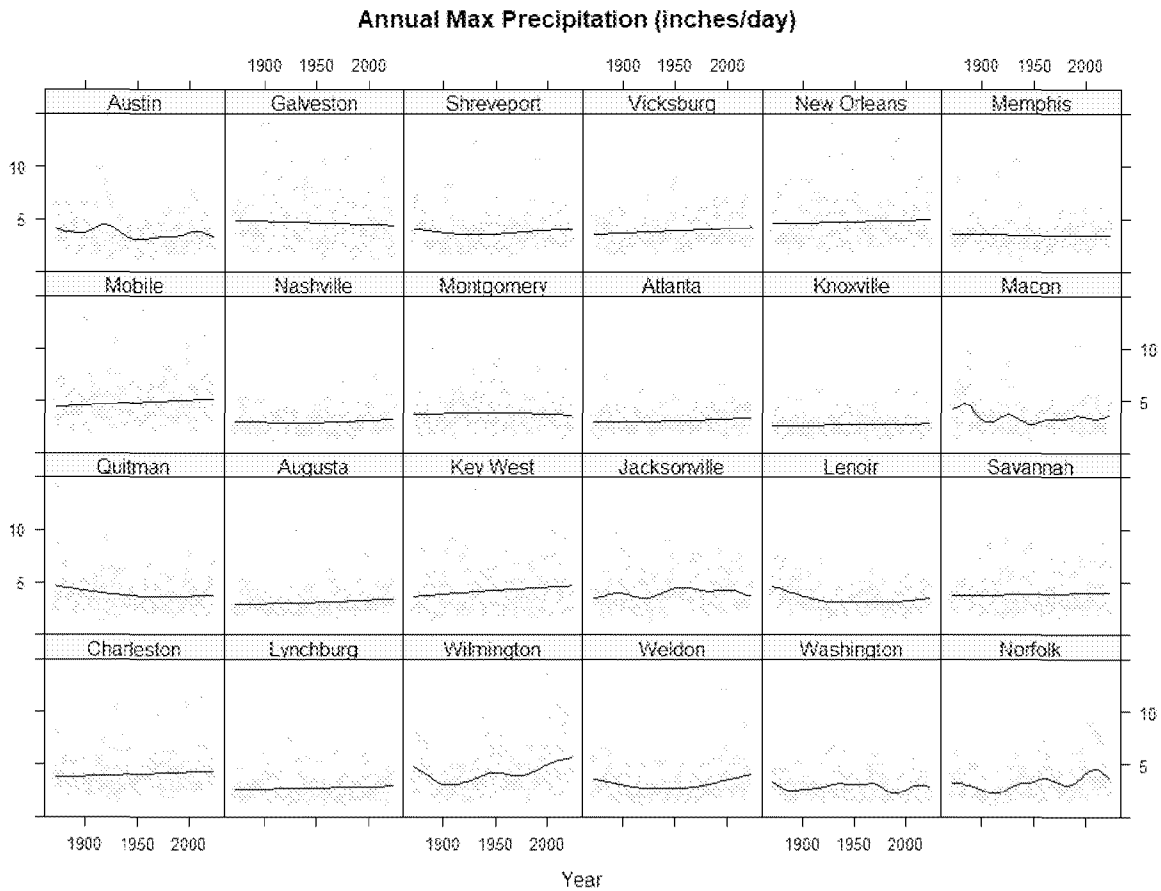


Figure 8.12 Annual maximum precipitation for 24 Southeast stations 1872 to present

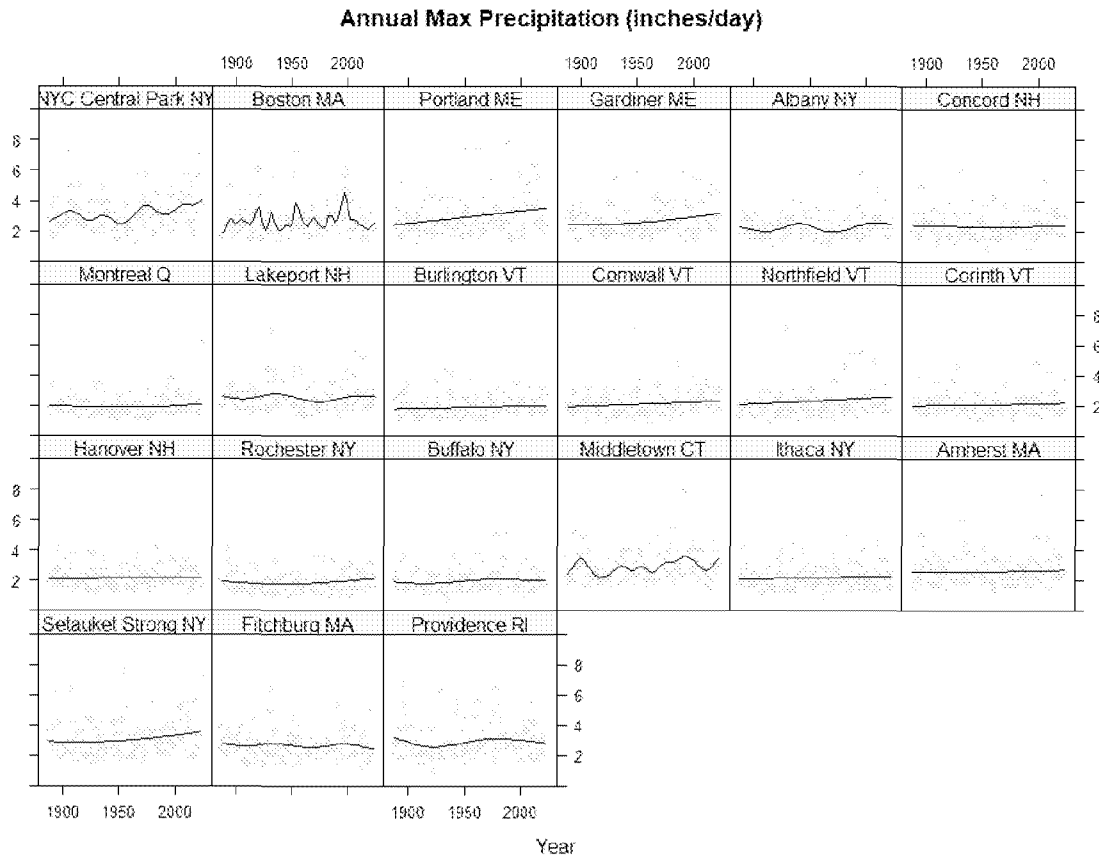


Figure 8.13 Annual maximum precipitation for 21 Northeast stations 1888 to present

Pacific Coast heavy rainfall events

The Pacific Coast receives considerable amounts of precipitation from Atmospheric River (AR) events which often last more than a day or two (e.g., Gershunov et al. 2017, Pan et al. 2024). The worst-known such event in recent history was the ArkStorm that occurred between December 1861 and January 1862, which dumped nearly 10 feet of rain in parts of California and submerged the entire Central Valley for weeks under as much as 15 feet of water (Brewer 1930, Null and Hulbert 2007). Paleoclimate research has found six megastorms more severe than 1861–1862 in California during the last 1800 years, occurring at intervals of 300 years or so (Porter et al. 2011).

SIDEBAR: Perils of short data records

San Francisco provides a good case study of the limitation of using short historical samples to characterize natural variability of extreme events. Suppose we use a 130-year sample of daily San Francisco precipitation from 1895 to 2024 and we look for 3-day, 5-day, 14-day and 30-day rainfall records. The results are as shown in Table 8.1.

Event	Record (inches)	Year
3-day	6.94	2023
5-day	8.55	2023
14-day	12.62	2023

30-day	18.93	1998
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Table 8.1: Extreme rainfall records, San Francisco, 1895-2024.

The records all cluster in the more recent data. 2023 appears to be an exceptional year and since it is near the end of the sample it would point to the possibility that the climate has shifted into a potentially more hazardous state.

But if we extend the record back to 1850 the picture changes. Table 8.2 shows that the record-setting events all happened in the 1860s. Furthermore 2023 is now not even in 2nd place but falls to 3rd or 4th. Also, comparing the records of the two charts the extreme precipitation events in 1862 and 1867 involved considerably more rainfall than the 1998 and 2023 events, with 14- and 30-day totals about 50 percent higher.

Event	Record (inches)	Year	Rank of 130-yr extreme
3-day	8.85	1867	3
5-day	9.80	1867	3
14-day	19.05	1862	4
30-day	28.25	1862	2

Table 8.2: Extreme rainfall records, San Francisco, 1850-2024.

The characterization of the range of natural variability is made even more remarkable when paleoclimate evidence is examined. Porter et al. (2011) discovered that in the past 1,800 years at least six megastorms were more intense than the devastating 1861-62 ArkStorm struck the region. Thus, such extreme events have impacted the region about every 300 years, though not since 1895.

This example illustrates the limitations of using relatively short climate periods (~130 years) to assess the character and range of natural variability in general and of extreme events in particular. Accurate representation of the full range of natural variability is necessary for any attribution analyses (see 6.4). Infrastructure planners, emergency management institutions and attribution scientists would understand the significant mischaracterization of the magnitude of a future extreme if based only on the last 130 years. In this case, a single time-sample of 130 years provides an underestimation of the extreme value by up to 50% determined when adding only 45 more years of observations. Compared to millennial-scale paleoclimate evidence, an even greater underestimation would occur.

We examine occurrences of 5-day deluges as follows. In a 130-year span there are 26 5-year intervals. At each location we computed the 5-day precipitation totals throughout the year and selected the 26 highest values. A single year may have more than one of the 26 heaviest. Each of those can be thought of as 1-in-5yr events. If there are no trends in precipitation then the total number of these events across all stations should be evenly spread out on an annual basis. In Fig. 8.14 we show the distribution in time of these events. The deluges associated with the massive 1997-98 El Niño event are readily apparent. While erratic, as is typical of these types of precipitation metrics, there is no indication of a tendency to become more frequent over time.